Routes for extending the lifetime of wind turbines

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Product Lifetimes and the Environment Conference Editorial

We are delighted to present the proceedings of the first international conference on Product Lifetimes and the Environment (PLATE). This ground breaking event, held in Nottingham, UK, included 5 keynote presentations, 62 papers and 6 workshops. Alongside the conference was an exhibition of prototypes, objects, artefacts, posters, photographs and films, details of which are provided in a separate catalogue.

Product lifetimes have become an increasingly important element in the debate on circular economy, resource efficiency, waste reduction and low carbon strategies for sustainability. Consequently a growing body of academic researchers, companies, independent think tanks, government bodies and other policy stakeholders have been addressing the topic in recent years. The aim of this conference was to embrace this emerging area of research, sharing knowledge and expertise in order to explore the influence that product longevity has on environmental, economic and social sustainability.

A multi-disciplinary approach to this topic is vital and contributions were thus invited from scholars from a range of backgrounds, including design, geography, anthropology, business management, economics, marketing, consumer behaviour, sociology and politics. The programme has been structured around seven themes:

- Design approaches to product longevity
- The role of product longevity in resource efficiency and waste reduction
- Strategies for product lifetime optimisation
- Cultural perspectives on the throwaway society
- Business opportunities, economic implications and marketing strategies
- Consumer influences on product lifetimes
- Policies, regulation and legislation.

Around 100 proposals for papers were submitted to the organisers in the form of abstracts. Following a peer review process, just under two thirds of these resulted in papers accepted for publication in the proceedings. We were very impressed by the quality of many papers and are grateful to have had contributions from researchers from many disciplines and 16 countries across five continents.

As editors of these proceedings, we are delighted to put together this collection of thoughtful papers on the topic of product lifetimes in the context of sustainability. We are confident that the proceedings will help to nurture discussion and debate on this important topic, as well as contribute to the growing academic knowledge in the field.

Tim Cooper, Naomi Braithwaite, Mariale Moreno and Giuseppe Salvia (Joint Editors)

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Using psychological ownership to guide strategies for slower consumption

Baxter W.L., Aurisicchio M. and Childs P.R.N.
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Keywords: psychological ownership; product meaning; object attachment; product longevity; access-based consumption.

Abstract: This study explores the extent to which the theory of psychological ownership can be used to understand and design for slower consumption through two strategies: product longevity and access-based consumption. To do this we employ a qualitative study investigating objects kept, discarded and used by participants. We find that the theory is useful in informing both product longevity research and access-based consumption. Both strategies benefit from a framework in which the motives and routes to developing object attachment are discussed. Longevity decisions made by users (i.e. keeping, disposing and engaging with objects) are determined by the ability of an object to fulfil the motives in the framework. Routes can be utilized to create more meaningful paths to ownership and attachment. Access-based consumption threatens all three motives for ownership and leaves the user with little meaning. Thus the theory helps explain the consumer reluctance to adopt access-based consumption models as they currently stand.

Introduction

Increasing product longevity and access-based consumption (e.g. product-service systems or other sharing models) are two strategies for slowing resource consumption to sustainable levels (Cooper, 2005). Product longevity generally concerns enhancing the user-object relationship, while access-based consumption redefines it. Despite promising directions in these areas (e.g. Chapman, 2005, 2010; Evans & Cooper, 2010; Tietze & Hansen, 2013; Tukker, 2004; Van Nes, 2010), additional consumer-facing research is needed to facilitate more widespread adoption of both strategies (Mont, 2008; Tukker, 2013). Within this context, we report a qualitative study investigating why individuals do (not) keep objects for a long time and do (not) prefer access schemes. We frame this research within the theory of psychological ownership—the mental state in which individuals feel the target of ownership is 'theirs' (Pierce, Kostova, & Dirks, 2001).

We posit that psychological ownership theory is useful in two ways. First, it addresses why and how individuals own objects. As the name suggests, this ownership is a psychological representation of the individual's relationship to the object and subsequently is bound by interactions rather than legalese. For example, an individual may legally own an object without ever taking possession of it (McCracken, 1986) or conversely, individuals may have feelings of ownership when no legal ownership exists (Pierce, Rubenfeld, & Morgan, 1991; Van Dyne & Pierce, 2004). This nuanced approach to understanding human factors through the lens of ownership should help explain the consumer concerns that have curbed access-based consumption models where companies retain ownership and offer short-term access to consumers.

Second, psychological ownership theory is valuable in understanding meaning creation and object attachment that could contribute to product longevity. That is to say that if object attachment is defined as a perceived psychological closeness to an object (Baumeister, Wangenheim, & Florian, 2014), then psychological ownership represents an extreme form of this closeness—one in which the object may become part of an extended self (Belk, 1988). Shu and Peck (2011) directly link psychological ownership to attachment and show how it contributes to loss aversion. Other studies support this link to loss aversion (Baer

& Brown, 2012; Kahneman & Knetsch, 1991) and highlight additional products of attachment such as higher evaluation (Franke, Schreier, & Kaiser, 2010; Reb & Connolly, 2007) and feelings of stewardship (Hernandez, 2012). In a wider perspective, we see psychological ownership theory useful in providing a coherent model for attachment (Baxter, Aurisicchio, & Childs, 2015a), the elements of which are stressed in a number of design-oriented attachment studies (Desmet & Hekkert, 2007; Mugge, Schifferstein, & Schoormans, 2010, 2006; Mugge, Schoormans, & Schifferstein, 2009; Norton, Mochon, & Ariely, 2011).

The remainder of the article is structured as follows: (i) introduce psychological ownership theory, (ii) discuss research questions and (iii) report key findings from the qualitative research including emergent themes for future research.

Psychological Ownership Theory

Psychological ownership is the mental state in which individuals feel that an object is theirs. The theory of psychological ownership describes the motives (the why) and routes (the how) leading to this mental state (Pierce, Kostova, & Dirks, 2003). It follows that ownership is a result of user experiences. In the perspective of existing experience design frameworks the motives and routes can be thought of as be-goals and do-goals, respectively (Hassenzahl, 2010; Pucillo & Cascini, 2014). Previous work by the authors has mapped and expanded this connection to create the framework in Figure 1 (Baxter et al., 2015a). This framework is bidirectional in that ownership motives drive actions and actions fulfil motives leading to ownership.

Motives

Psychological ownership is driven by three motives: efficacy and effectance, self-identity, and having a place to dwell (Pierce et al., 2001, 2003). Efficacy and effectance is the desire to feel competent through the ability to impact one's surroundings. Self-identity is the desire to create, continue, and/or transform one's public and/or private identity. Having a place to dwell is the desire to gain and preserve physical, emotional, and mental security through familiar surroundings.

Routes

There are three routes to achieving psychological ownership: control, intimate knowledge, and self-investment (Pierce et al., 2001, 2003). Control is the ability to use or

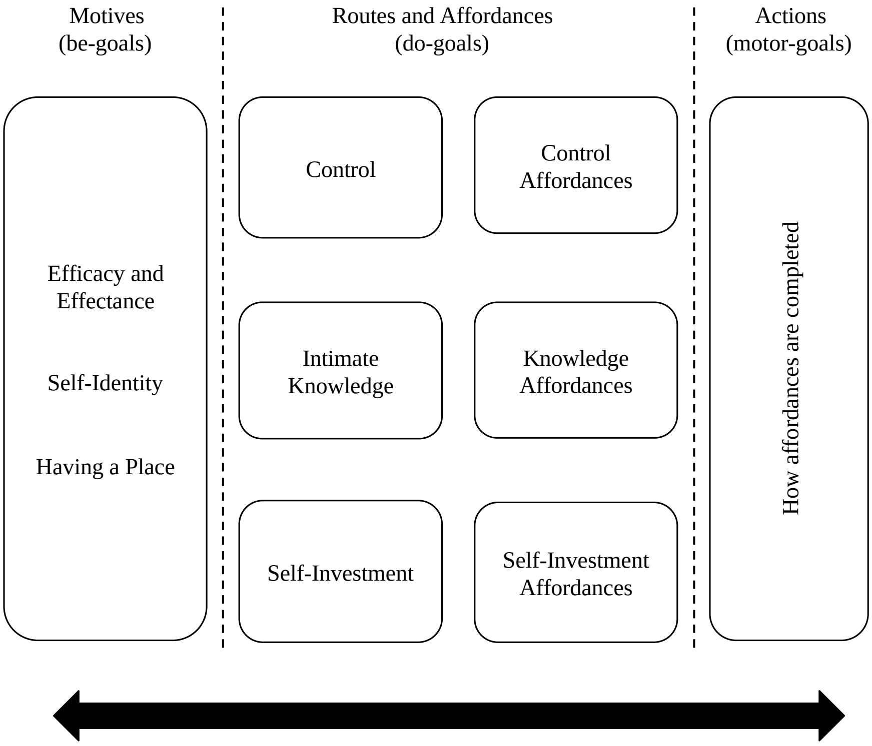

Figure 1. Framework for psychological ownership-based attachment. Source: Baxter, Aurisicchio, & Childs, 2015a.

transform an object when and how desired. Intimate knowledge comes as users acquire information about the object. Self-investment is the expenditure of time, money, physical effort, and/or psychological energy into an object. Importantly, a prerequisite to these routes is that the object attracts or engages the user.

Research questions

Three research questions guide our evaluation of psychological ownership as a means to address access-based consumption and developing object attachment for product longevity.

RQ1: Are desires to keep products (rather than dispose) guided by the motives in psychological ownership and fulfilled via the routes?
RQ2: Are desires to dispose of products determined by an object no longer meeting these motives?
RQ3: Can reluctance (willingness) to engage in second-hand acquisition and access-based consumption is understood through the perceived failure (ability) of an offering to fulfil the motives within psychological ownership theory?

Through answering these questions we hope to inform future directions in researching and designing strategies for slower, sustainable consumption.

Methods

We interviewed ten participants for this research. Participants consisted of six females and four males, aged from early 20s to late 60s. All interviews were conducted in London, England though the participant's cultural backgrounds consisted of 8 countries through North America, Asia, and Europe.

The intention of the interview was to understand psychological ownership theory as applied to product longevity and access-based consumption. To explore this, we used semi-structured interviews to inquire about interactions with objects: 1) kept for a long time, 2) disposed though still functional and 3) used previously either through second-hand acquisition or access schemes. Participants were asked to identify one or multiple objects in each of these three categories and reflect on them. The choice of the object discussed was left up to the participants. Objects explored included: antiques, consumer electronics, clothing, furniture, and spaces. In each interview, questions regarding the motives and routes of psychological ownership explored nuances of the user-object relationship. Further questions tried to qualitatively assess the extent to which participants felt the object was 'theirs'. Where possible, interviews were conducted in the participant's home or work where objects discussed could be seen and described in greater detail.

Each interview was documented through notes and audio recording. Directly following the interview, notes were reviewed and any insights or themes were recorded. Recordings were transcribed and all resulting data was analysed in an iterative process to extract themes. All names have been changed to preserve anonymity of respondents.

Two limitations of this research are worth noting. First, our findings are limited by the number and background of participants. Ten participants are not enough to understand the distinctions caused by personal values and cultural influences. Second, we are limited by the number of interactions examined. The way a person interacts with consumer electronics differs from a pair of shoes. Future studies will need to address these limitations in order to further validate the extent to which this framework can be generalized.

Findings

Interviews revealed a strong agreement between psychological ownership theory and participants' rationale for keeping, disposing, and engaging with objects. Perhaps equally important, none of our interviewees gave reasons that could not be understood in the context of the theory. The interviews also highlight psychological ownership theory's usefulness in describing why consumers choose ownership rather than access-based consumption schemes. The next sections discuss the findings for product longevity and access-based consumption in detail.

Product longevity

All participants reported significant attachment to the objects that they had kept for a long time. Though not always described in terms of feelings of ownership, motives were consistent with feelings of attachment. This attachment is only as strong as the object's ability to fulfill the motives and thus, disposal resulted when an object no longer fulfilled the motives. Several themes emerged in this regard.

'Efficacy and effectance' communicate users' ability to influence their surroundings and feel competent. This differs greatly if the object is used as a tool to influence some end task or if the object is an end in itself. If an object is used as a tool, attachment (and subsequent longevity) is dependent on the perceived ability of the object to fulfil a task relative to alternatives. Thus, technological innovation often drives desires to keep or replace objects. Laura described this with regard to her laptop:

> *… I would hate to get a new product. Unless it would enable me in a way my existing product doesn't I wouldn't get it. Even then, [new features need] to be very different. The retina display, for example, had little draw for me.*

If an object is an end in itself, the danger is in the user no longer being able to explore and discover new things about the object. Greg, a video game enthusiast, explained that video games are only useful until he has beaten the game or feels there was little or nothing else to discover at which point he would throw the item away. Matthew shared a similar sentiment about a leather chair he "got bored with" and decided to dispose. Product longevity benefits from design that is complex enough to keep users engaged through continuous discovery.

'Self-identity' is susceptible to changes in self-image (e.g. advancing in society, maturing, fitting a new position) and cultural influences (e.g. trends). The key is to find objects that span both of these. Shirley talked about a wool coat that she has had for over a decade. The coat passed with Shirley through high school, college, and a professional career and was used frequently at all stages of life because it has a timeless design. Shirley used it when she was younger because it was pretty but she has since transferred it to her professional wardrobe because it looks elegant and mature. Longevity is more likely to occur if designers understand and account for when and how self-identity transitions.

'Having a place' provides security to individuals through familiar objects. Often, objects in the same setting compete for this motive. For example, small objects (books, accessories, artwork, furniture, etc.) are often considered within a larger object (house, room, car, etc.) and individuals try to reconcile a desired place these provide together. Ashley showed this trade-off when disposing of a large sofa in her flat that did not contribute to the room:

> *It looks horrible. In terms of hygiene a bit weird. (…) It took up too much space in a small flat which would have been useful. We could have had our living room designed better without the sofa.*

In terms of product longevity, the strongest motive seems to be having a place when it offers psychological security. This psychological security often came from cultural emblems (e.g. an object from one's home country) or when the object reflects specific experiences that create nostalgia. In other instances it provided a psychological state of mind needed in the moment. Shirley described how clothes help her feel "confidence and in a ready state of mind." Greg explained that his attachment to his PlayStation is largely because of the place it provides:

> *I can sit down and play the PlayStation but also it gives me that spot, you know I live with my partner, we are comfortable, we are together 24/7 but if I want to I can have my break. (…) I know I can shut the door and put my headphones in and escape.*

Routes to psychological ownership help users create or discover meaning. We find a typical directionality between user and target objects of ownership (see Figure 2). Control and self-investment are typically things done by the user to the object, whereas intimate knowledge is the result of the user interpreting information communicated by or about the object. Understanding these directions helps inform various approaches (e.g. co-creation, mass customization, designed affordances, associated service offerings, marketing and promotion) to enhancing attachment or ownership.

From the interviews we have tried to extract general paths to attachment as they relate to the routes. This is the result of inquiring how users engaged with objects over time and how they felt their attachment changed accordingly. We found that paths are primarily determined in three ways. First, significant increases in attachment occur when users engage in focused interactions with an object such as configuring, repairing or researching an object. Second, gradual increases in attachment result over time due to improved ability to control the object, routine effort required in interacting with the object and knowledge received through use. Finally, used objects may create feelings that they are foreign—belonging to someone else. We have depicted common paths of attachment in Figure 3. Path B represents a typical path of attachment for an object—large initial attachment and continued increase as the user learns to better control and cares for the object over time. Path A results from heightened attachment activities (e.g. mass customization) making a steeper slope in the initial attachment. Path C occurs when the object is standardized so as to limit progression through focused interactions. Finally, Path D occurs when users engage with objects used by other people and feel the object is not theirs until they cleanse it from traces of the previous owner.

An example of these paths is seen with a car. Path A might represent an owner's attachment to a car that has been customized and significant work has been put into. Path B would be a car as normally purchased. The

focused interaction in this path being the search for the car and money (e.g. self-investment) spent. Path C might be a company car that a person did not choose or purchase but does get

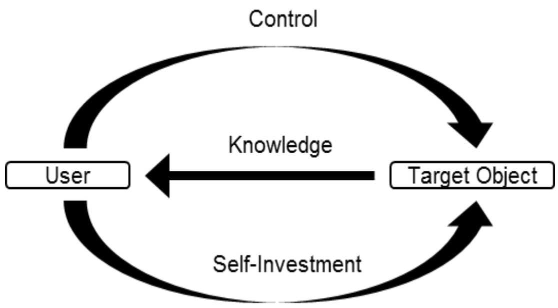

Figure 2. Directional nature of routes.

to know through frequent use over time. Finally, Path D might be a car acquired second-hand or temporarily accessed with reminders of the previous user.

Feelings of aversion due to previous users were a common theme in the interviews. Often these feelings result from the sensorial properties of the object and can be accounted for, to a large extent, in design (Baxter, Aurisicchio, & Childs, 2015b). In other cases, the feeling that an object belongs to someone else eliminates the possibility of use altogether. Greg, talking about second hand goods, explained:

> *I don't think I have ever owned something second hand because… it's bringing someone else' energy into it and I would not have that. I don't have a problem bringing someone else's energy it's just, just not [for] me. I prefer to introduce my energy to anything materialistic.*

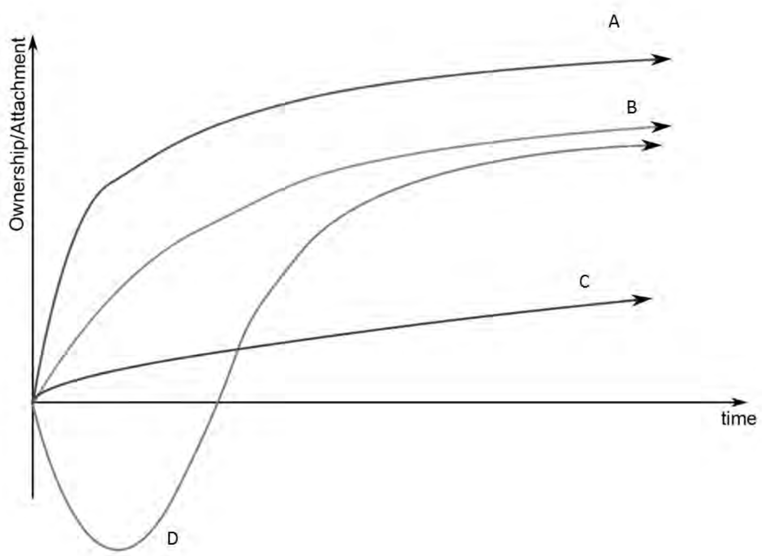

Figure 3. Paths for attachment.

Finally, we do not suppose that psychological ownership will always produce positive environmental results since it may also create an "It's mine so I will do with it as I please" attitude. In such cases, incentives around the result of owning an object (e.g. opportunity to resell, fine for disposal without recycling) might best encourage positive behaviour.

Access-based consumption

Access-based objects are, by design, transient and they consequently threaten all three motives. Having a place requires developing familiarity with the object so it offers security for the user. Such familiarity is threatened by short-term usage. Typical concerns in this context are around cleaning practices and fear that other users will damage the object. Short-term usage is particularly damaging in that it allows users to engage with an object in a neutral state but it may raise feelings of disgust or aversion because the object was in another person's place (the bottom of Path D). These concerns could greatly change object interactions and brand perceptions since the object goes from representing a psychological comfort that contributes to the user's place to a transient condition of use. Vanessa explained such feelings with a coat purchased second-hand that smelt of the previous owner. She went through great effort to remove the smell but those in access-based models may not be willing to invest in such effort.

Self-identity is also threatened under access-based consumption due to transient use. This is because in transient usage, objects, and their meaning, are not easily transferred to the user's extended self. Ashley explained that collecting designer clothes helped her—as a fashion designer—"gain a piece" of the designer behind the clothes. Brian explained that he could never rent a watch because he viewed it as having meaning to him and as a memento—an object remembering him that he could pass on to his children. These situations are very difficult under access.

Efficacy and effectance is clearly the driving factor behind access schemes (e.g. improve usability and convenience) and when objects only focus on this motive access schemes may be most likely to succeed. An example was Matthew's ski rentals. He used to own his own skis but was discouraged by airline fees and the hassle of carrying them around when traveling. A number of years ago he switched from owning to renting skis once he gets to the resort but he still finds that good service to ensure quality and functionality is essential. This designed service is the key to successful access models. If the service is too obtrusive it causes users to feel that they are no longer in control and their efficacy and effectance are threatened.

Conclusions

This research hypothesized that the theory of psychology ownership and the framework presented in this research to contextualise the theory within design are useful in approaching the slower consumption strategies of product longevity and access-based consumption. Product longevity benefits from the framework as it offers a means of developing object attachment. Attachment is driven by a desire to fulfil the motives in the framework and is realized through the routes. Likewise, attachment is broken by an object's inability to fulfil the motives. The directional nature of the routes can guide thinking around tasks aimed at enhancing attachment.

Findings also show that access-based schemes threaten the motives for psychological ownership and help explain why consumers prefer ownership rather than access. The framework informs shortfalls of many access schemes but also helps provide directions for making a more appealing offering. For example, technology may be better utilised to create a place for users in individual usage scenarios through tactics such as saved preferences. The opportunity also exists for design to better guide paths of attachment/ownership and optimize user experience while slowing consumption.

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We would like to thank all the participants for their time and stories. We would also like to thank the reviewers for their valuable feedback.

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Should energy labels for washing machines be expanded to include a durability rating?

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Keywords: labelling; durability; washing machines; energy efficiency; impacts.

Abstract: Washing machines are a key household appliance that can be found in the majority of UK homes. Over 2.5 million are sold in the UK every year and account for one of the highest material and production impacts of householder products in the UK (WRAP, 2011). Energy efficiency ratings are provided as a method for consumers to make an informed purchasing decision and were brought in by EU legislation to reduce energy use and enable users to reduce running costs, as it is known that the greater environmental impact of a washing machine is during use. From 2014, all washing machines sold must be at a minimum A rated, with ratings increasing to A+++. However, under this current labelling system the embodied impacts and durability of the machines are ignored.

Through semi-structured interviews with consumers, manufacturers and distributors, this paper explores different perceptions of longevity and expectations of performance and durability. The paper explores whether energy labels should be expanded to include durability information, as this could enable consumers to make a decision based not only on cost and energy efficiency but also on expected lifespan. Existing manufacturer's guarantees may give an indication of the expected durability of the product and this is investigated to explore if there is a positive correlation. The findings will further discuss the potential impacts of providing durability information and how this could enable manufacturers and consumers to shift towards a low material and energy future.

Introduction

Durable products, defined as those which have a longer lifespan (Baaker, 2014), have a positive impact on sustainable practices, through reduced waste and CO_2 emissions and are economically beneficial to the user (Stahel, 2010). WRAP(the Waste and Resources Action Programme) has identified washing machines as a priority product contributing significant resource impact on the UK market (WRAP, 2013). Estimates suggest 97% of UK households own a washing machine and the market is expected to grow by at least 18% between 2014 and 2019 (Mintel, 2014). With an expected lifetime of six years, many consumers replace washing machines because they have either failed or are unreliable (WRAP, 2013). This means that most individuals will own several machines over their lifetimes, increasing environmental impacts from materials. Implementing durability as a key characteristic of washing machines should increase both the functional performance and service life of these appliances (Stahel, 2010). Communication of durability by manufacturers and retailers and understanding by consumers is an integral part of ensuring lifespans are increased.

The meaning of durability is open to varying interpretations (Stahel, 2010). As a characteristic durability can be linked to products that have lifetime guarantees or that have parts that can be updated or modified (Van Hinte & Bonekamp, 1997). Durability is not limited to the materials and design of a product, but also a product's capability of maintenance and its satisfactory performance which implies its functionality over time (Stahel, 2010). Durability is also influenced by how the consumer uses the product. When selecting products consumers generally research particular features (Lancaster, 1966) and product information signalled through brand and labels (Sammer & Wustenhagen, 2006).

Brands and labels fulfil two main functions for consumers, they communicate the intangible product characteristics (information functions, e.g. quality) and provide a value in themselves (value function e.g. prestige). However durability may not always be consistent with the brand, price and perceived quality of the washing machine, which confuses the consumer's understanding and expectation of how long the product will last.

The significant resource impact of washing machines is acknowledged (WRAP, 2013), yet durability and embodied impacts are not included in the current labelling system, and as a product it hasn't been considered in current research addressing durability labelling (Cooper & Christer, 2010). This paper considers the feasibility of expanding labelling to include durability ratings for washing machines, acknowledging the potential impacts of durability labelling for consumers and manufacturers.

Effectiveness of existing energy efficiency labels

The European energy label is a compulsory label that is applied to all home appliances and light bulbs sold within the EU. The label was first commissioned because the most resource impacts were identified to be during the use phase (Truttman & Rechberger, 2006). Figure 1 shows an energy efficiency label for a household washing machine, highlighting the different information requirements

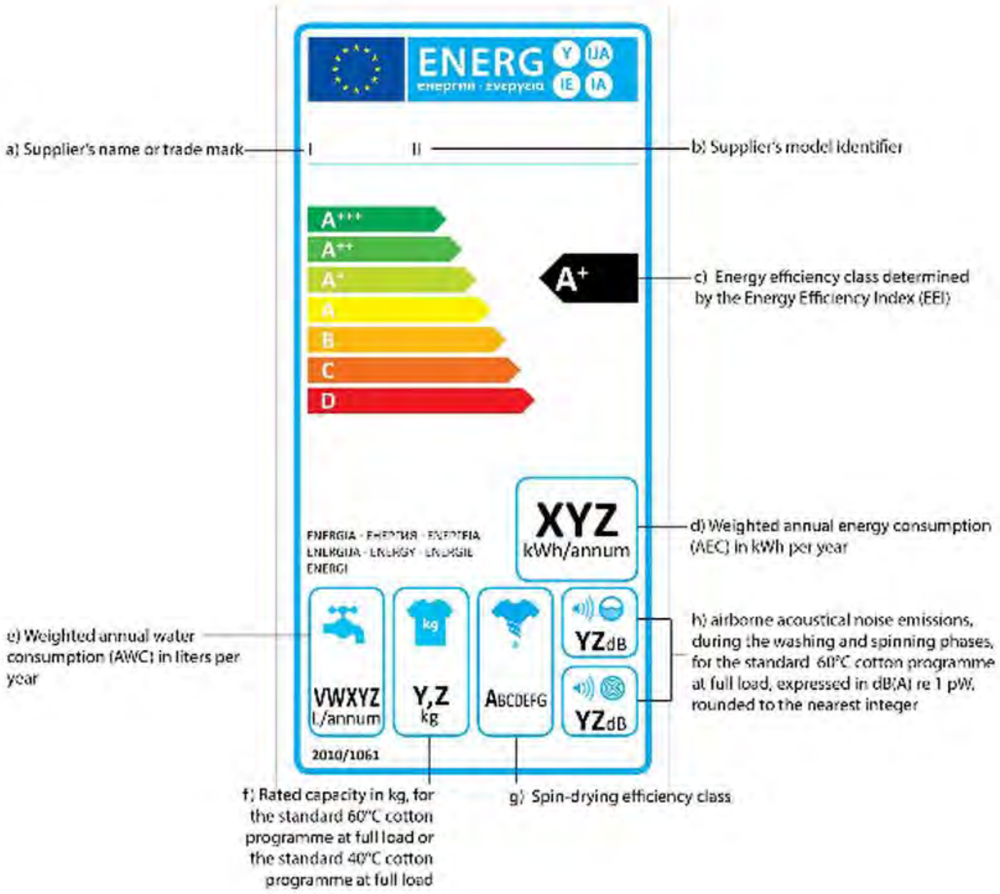

Figure 1. Energy Efficiency Label for household washing machines. © Source: European Commission, 2010.

Different energy efficiency classes of household washing machines exist according to the Energy Efficiency Index (EEI) in which A+++ is the most efficient and D is the least efficient (European Commission, 2010). The Energy Efficiency Index is determined by calculating the energy used in kWh per year at the standard 60°C full and partial loads and partial 40°C load, based on 220 standard washing cycles in a year, equating to 4.2 washing cycles per week. As of 2014, washing machines can only be rated in the UK as A+++, however other ratings do exist in the market (Which?, 2014).

Sammer and Wustenhagen (2006) found that energy labels are important in guiding consumers' buying decisions. Their research shows a willingness to pay more for A+ rating and above. However, Which? (2014) found that some A+ machines are cheaper to run than A+++; based on the 40°C cotton program (Mintel, 2013). Running costs vary according to peoples' preferences on washing temperatures and cycles. Mintel (2013) found a third of consumers mostly wash clothes at 30°C, and that 1% of the population washes at lower temperatures (20°C or less). This highlights the importance of laundering practices in relation to energy efficiency.

Consumer understanding on durability

Although the Ecodesign Directive (2009/ 125/ EC) has enabled the Commission to act in implementing measures on extension of lifetime, consumers feel that there is no reliable, information on durability for washers (DEFRA, 2011). In contrast, in 2013, the Commission drew on the Eco-design Directive to have an eco-label for vacuum cleaners that specified both energy consumption and minimum component lifetime requirements (European Commission, 2013). For washing machines, the Directive (2000/45/EC) addresses lifetime extension by implementing two year manufacturer warranties as standard. As such, consumers assess the durability of washing machines through the warranty offered, and their perception of brand to estimate how long the product will last (WRAP, 2013).

In absence of reliable information on durability, consumers use intrinsic and extrinsic cues (Schiffman and Kanuk, 2001) to judge how long a washing machine will last. Intrinsic cues reflect the physical characteristics of a product. Thus when buying a new washing machine, consumers would like to see evidence of product testings, see independent testings and reviews from external associations such as Which?, get information on-line and on the shop floor, and be able to check online product reviews to judge how long it will last (WRAP, 2013). Extrinsic cues are external to the product and include price, brand or store image. Brand could be considered as a proxy of quality and reliability, and indicator of durability (Cooper & Christer, 2010). Many premium washing machine brands use marketing tactics to advertise longevity. For example, Bosch uses the campaign 'Design for Life', or Miele, widely known for their advertisements promoting longevity (Figure 2). Consumers considered reliability and quality as significant attributes when purchasing a washing machine (Wrap, 2013). However, Which? product tests found that premium brands are not necessarily the most reliable. According to DEFRA (2011) proxies of brand and price were considered by consumers as unreliable indicators to assess product lifetimes as more expensive products do not always last longer than less expensive, lower quality ones. The next sections, explains a mix research methods approach, and presents quantitative and qualitative findings to understand if energy labels for washing machines should include a durability rating.

Figure 2. Miele print ad (released March 2003) © http://www.advertolog.com

Methodology

Firstly the energy consumption between an A+ rated machine to an A+++ machine of different brands were calculated, from this the associated price and carbon emission impacts were estimated. The embodied emissions were estimated to understand if a focus on durability and lifespan could save more carbon than a continued focus on in-use energy. To make these analyses, different models and brands of freestanding washing machines were chosen (Table 1). According to Mintel (2014), some of these brands are leaders in the market, others are premium brands, or new players. The models analysed were chosen according to their energy rating and price range: A+ washers with a price range between £200-£300 and A+++ washers with a price above £300.

Brands analysed to calculate the carbon and embodied emissions	Brands analysed to understand the type of information provided to UK shoppers
Hotpoint - Leader in the market	Hotpoint - Leader in the market
Indesit - Leader in the market	Indesit - Leader in the market
Becko - Leader in the market	Becko - Leader in the market
	Bosch-Siemens - Leader in the market
	Samsung - New player
Miele - Premium brand	Miele - Premium brand

Table 1. Brand and model considered.

An online search was undertaken to understand the information provided to UK shoppers and assess if these could be used to predict the lifespan of washers. The research was limited to an online search, as Mintel (2014) estimates that 40% of washers and dryers are bought online, major UK retail players have an online store, 57% of people will check prices online before buying , and 23% of consumers will use online product reviews to assess product lifespans (Mintel, 2014, WRAP, 2013). The brands and models analysed are shown in Table 1. The analysis compared fourteen different models of these brands of washers, according to their energy rating (e.g. 7 A+ and 7 A+++). The online search also considered where people shop for washing machines, as information displayed at the point of purchase is important (Cooper & Christer, 2010). These retailers are key players in online retailing (Mintel, 2014) and are shown in Table 2.

Type of retailer	Retailer(s)
Traditional Retailer	Curry's, John Lewis and Argos
Supermarket Online	Tesco Direct
Independent Group	Euronics Buying Group
Pure Online Retailer	Amazon, AO.com
Selling online via partnerships	Next Home with DRL

Table 2. Retailers considered.

The data from the online search was classified in six categories which will be described in the Findings and Discussion section. A comparison of these categories was made between brands and data collected from the seven retailers. These findings were then complemented with data from a small sample of semi-structured interviews with consumers and some traders that retail and maintain large household appliances.

Findings and discussion

This section presents preliminary findings to explore if a focus on durability and lifespan could benefit the environment and the consumer.

The impact of improving the energy efficiency of washing machines

As discussed in Section 2, legislation has pushed for improved energy efficiency of washing machines to reduce energy use and carbon emissions. However, as can be seen in Table 3, efficiency improvements become more incremental as the scope to improve energy efficiency decreases. This section explores the improvement in energy consumption and the associated price and carbon emission impacts of moving from an A+ rated machine to an A+++ machine.

Table 3 shows a comparison of the different energy ratings and annual consumption for four different brands. The energy consumption has been calculated per kg of capacity so that energy consumption of washing machines of different loading capacities can be compared. It can be seen that in each of the examples there is an energy saving by upgrading to the higher energy rated machine. This energy saving in turn delivers a cost and carbon emissions saving (although these are minimal), which have been calculated based on the Energy Savings Trust, (2015) estimates of standard electricity cost at 14.05p/kWh and carbon dioxide emission factor for electricity of 0.490 kgCO2e/kWh. In particular, the difference in energy consumption between an A++ and A+++ machine is very small, 1.57KWh/kg capacity, compared to a 5.43kWh/kg capacity difference between the A+ Beko machine and the A++ Miele machine. It should be noted that these energy and associated savings are calculated based on the energy consumption disclosed as part of the energy rating, actual use in terms of cycle type, time and temperature will vary from household to household and thus so will the potential savings.

Brand	Indesit		Hotpoint		Beko		Miele	
Energy Rating	A+	A+++	A+	A+++	A+	A+++	A++	A+++
Energy Consumption (kWh/kg of capacity)	32.67	24.00	32.00	23.50	31.00	24.00	25.57	24.00
Energy Difference (kWh/kg of capacity)	8.67		8.50		7.00		1.57	
Price Impact (£)	1.22		1.19		0.98		0.22	
Emission Impact (kgCO2e)	4.25		4.17		3.43		0.77	

Table 3. Comparison of the different energy consumption of a range of washing machines, exploring the potential energy, cost and carbon savings when upgrading the energy efficiency of the machine.

It is not only the in-use energy consumption of a washing machine that should be considered, washing machines contain energy intensive materials such as steel, concrete and aluminium, which amount to its embodied carbon. Skelton & Allwood (2013) estimate the embodied emissions of a washing machine to be 270 kgCO2e. This becomes relevant when deciding where emphasis should be placed in the life cycle for emissions reduction. Are there greater carbon savings from continuing to improve energy efficiency, or from improved durability and maximising the life span of the already expended embodied carbon of the machine? Figure 3 explores the incremental, yearly energy savings from upgrading to a higher energy rated machine, showing where this falls in relation to the average embodied carbon of a washing machine. For the purposes of this graph, 270 kgCO2e is assumed to be an industry average, applicable across the range of washing machines in this study. It is also assumed that this does not significantly vary according to the durability and lifespan of the washing machine. An average capacity of the case study machines, of 7.6kg, is taken to ensure results are comparable.

From Figure 3 it can be seen that in the earliest case, for Indesit and Hotpoint examples, the carbon savings from upgrading an A+ machine to an A+++ machine reach the embodied carbon of the machine after approximately 8.5 years. For the Beko example this increases to just over 10 years. Considering the expected lifespan of a washing machine is six years (WRAP, 2013) this demonstrates that from an emissions perspective that there is an increase in whole life emissions if a A+ machine where upgraded to an A+++ machine. The carbon savings are even smaller from the upgrade from an A++ machine to an A+++ machine, with the total savings after 15 years not reaching even half of the embodied carbon of the machine. In this case, it would take approximately 46 years before the carbon savings from the improved in-use energy consumption reached those of the embodied carbon. This indicates that for washing machines of A+ standard (and above) there should be a much greater focus on durability and lifespan, to reduce machine replacement and thus minimize embodied carbon emissions, rather than continuing to focus on ever smaller, incremental improvements in-use energy.

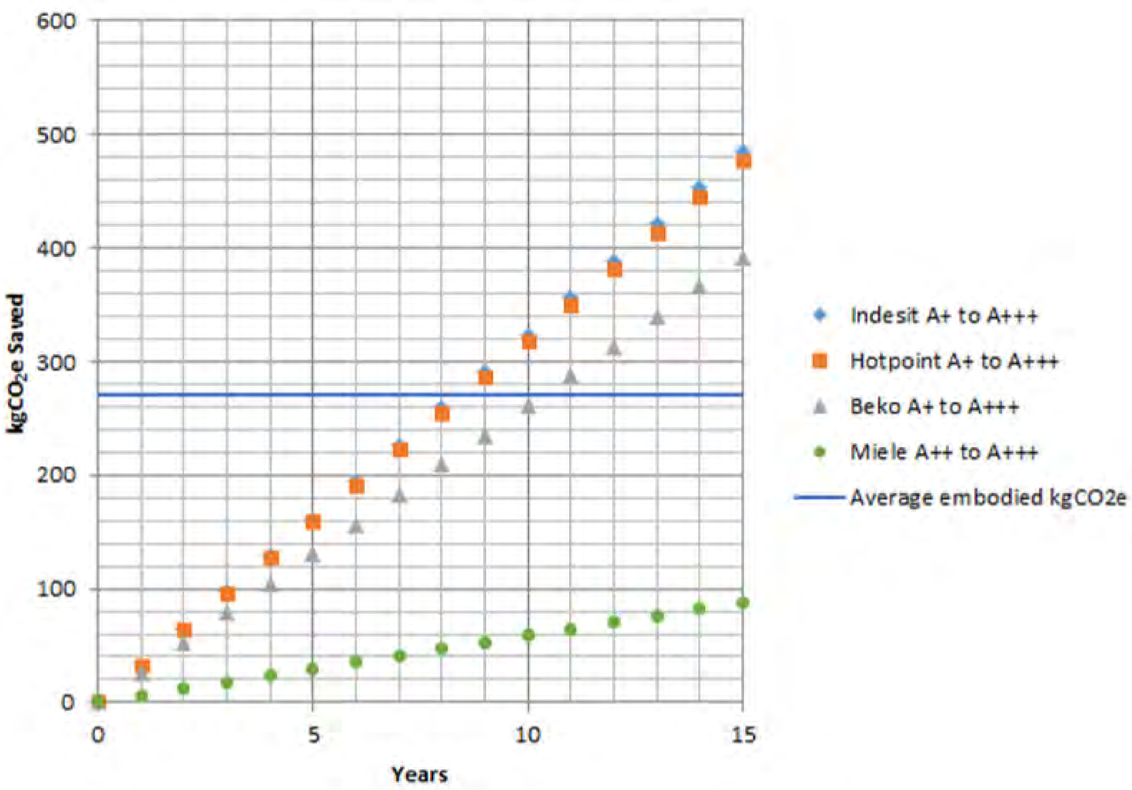

Figure 3. Incremental CO2e savings between different energy rated washing machines.

Current durability information provided to consumers

The analysis above calls to shift the focus from incremental improvement in-use energy to a greater focus on durability and life spans. However to make this change effective, durability features should be clearly communicated to consumers. This section presents the six categories on current information provided to consumers by manufacturers and retailers.

a) Types of information provided

Manufacturers' and retailers' display information about main technical specifications, functions, structural characteristics, washing programmes and options, as well as performances including spin speed, capacity, water usage and noise levels. Only Miele, indicates durability by stating the expected years of use, and just Amazon makes this clear for this specific brand.

b) Guarantees/warranties

As a minimum, manufacturers are obliged to offer a two year warranty. However, the law does not specify if this should include both labour and parts. Some manufacturers just offer 1 year warranty including labour and parts, plus one to ten years warranty for parts. The length of the warranty depends on washing machine model, specific embedded technologies and on specific deals with selected retailers. In addition, some manufacturers offer extended warranties through independent providers with an extra cost. These cover labour and parts. Table 4 shows a comparison of warranties offered by the six brands analysed. All retailers will offer the warranty provided by the manufacturer. However, some of them will offer certain deals that the manufacturer does not. For example John Lewis would offer a second year guarantee that includes labour for all washers without an extra cost.

Brand	Warranty offered
Indesit	1 year warranty labour + parts, and 5 years warranty for parts.
Hotpoint	1 year warranty labour + parts, and 10 year warranty for parts upon online registration of their product.
Beko	1 year warranty labour + parts. Offers an extended warranty up to 4 extra years through an external provider.
Bosch-Siemens	2 years warranty labour + parts, and 10 years warranty in parts if the washer has EcoSilence Drive™ (a specific motor that claims to be more efficient). Some Siemens washers have 5 year warranty (labour + parts) in specific models purchased from specific retailers.
Samsung	2 years warranty labour + parts, 5 years warranty (labour + parts) for specific models purchased from selected retailers, and 10 year warranty in parts if the washer has a Digital Inverter Motor.
Miele	2 and 5 years warranty labour + parts, depending on the model and 10 year warranty for an extra cost.

Table 4. Warranties offered by 6 different brands of washing machines.

c) After sales services including repair

For manufacturers and retailers, after sale services are linked to those offered by the warranty and extended warranty. Just Curry's offers a repair service for those washers that are out of a warranty, except for Miele products.

d) Marketing and sales specifying durability or life spans features

Some manufacturers advertise specific features of their brand that resemble durability features. For example, Samsung's promotional material refers to the design of their motor as a proxy for durability. However, not all brands use the same strategy. In addition, retailers advertise durability features for certain brands. For example, Euronics refers to a Siemens washer by saying:

> *'With a washing machine from Siemens, you know you're getting a quality product from a leading household name. We stock only the best brands, and we understand the importance of a reliable washer that will last you for years.'*

e) Buying guides by retailers

Most retailers offer a buying guide except Amazon and Ao.com. The guides offer information informing which washing machine is best, including, type of washing machine, capacity, washing programmes, performances, energy efficiency and the environment, installation, recycling and disposal services, latest technologies and reliability. The latter, is the only attribute that relates to durability.

f) Rated attributes in online reviews

All the brands studied, except Indesit and Miele, have an option to review their machines online. The reviews include attributes such as ease of use, noise, value for money, range of functions, washing results and build quality. Build quality, is assessed by Hotpoint and Beko and is the only attribute that is a proxy of durability. All retailers, have an option to review the washers they sell online, build quality is considered by most retailers except John Lewis, Argos and Amazon.

The feasibility of durability labelling

The sections above demonstrates the need to provide consumers with clear durability information. This is supported by interview findings which emphasize the complexity of interpreting durability at user level. For consumers, expectations of lifetimes could be subjective and influenced by brand and perceived quality, past experience, needs and on occasion time expected to live in a property. WRAP quotes the expected lifetimes of washing machines is six years (2013), however, Which? quotes 12 years (2014). The consumers interviewed gave a varied range of years which reflected the disparity between expectations. Defra found that perceptions of durability can be fluid between individuals making it difficult to generalise its meaning (2011). The interviews demonstrated that durability was not a characteristic that these consumers consciously considered at the time of purchase and instead they used terms like quality as an indicator of expected lifespan. Having a clear indication through a labelling system should therefore encourage a more standardised expectation of washing machine lifetimes, and in turn this could motivate manufacturers to ensure that their machines are designed and made to last longer. More provision should be made for repair and maintenance and availability of spare parts which could see manufacturers developing business and thus profit through the offer of localised services.

Interviews confirmed that the manufacturers' standard guarantees are important as a mark of reliability which may link to durability (WRAP, 2013). However, there was little interest in extending guarantees or investing in repair and service options from these particular consumers. This may indicate that consumers do not always see value in maintaining and repairing products as they are expected to only last a short amount of time and repair can be expensive (McCollough, 2009). According to the interview findings, consumers stated that expected years of use would be a clear indicator of durability. Therefore communicating how many years the appliance will last, could create shifts in consumer behaviour and attitudes towards the care and maintenance of washing machines as the consumer sees it as having a longer service life. However, discussions with traders demonstrated that although in principle this is a good idea for consumers, it may not be embraced by manufacturers who would see labelling lifespan as a threat to existing business models. For labelling to happen manufacturers need to see durability as a competitive advantage and commercially viable.

Mintel have seen a significant change in consumers' energy saving laundry habits which has led to increased sales in energy efficient appliances (2014). In support of this, interview findings evidence the significance of energy-efficiency as a cost saving measure. Although they considered the importance of efficiency rating at the time of purchase there was not an obvious correlation between the machine's efficiency and its durability from either the technical specification of the labelling or the consumers' perspectives. If consumers were to see that having a durable, longer lasting machine could be economically beneficial they may be willing to invest in such appliances.

Conclusions

Although further research is needed, it is evident that durability labelling would benefit both the consumer and the environment by ensuring washing machines are kept in use longer thus reducing resource impacts. Durability labelling would be closely bound to the design, manufacture, maintenance and reparability of washing machines, yet encouraging manufacturers to endorse such a model needs further work. Just as legislation supported the implementation of energy efficiency labelling, it could also encourage durability labelling.

As washing machines contain energy intensive materials and have significant embodied carbon impacts ensuring durability through longer lifespans would be an effective carbon reduction strategy. Although it has been assumed that embodied carbon does not significantly vary according to the durability and lifespan of the washing machine, further research intends to explore this relationship in more detail. The paper has argued that despite the impacts durability labelling might have on manufacturers and retailers it is a feasible method of moving towards a low material future. The authors intend to develop this research further to strengthen the case for durability labelling by demonstrating its potential benefits to manufacturers and retailers. By communicating durability these labels should ensure that washing machines are able to have a longer service life.

Acknowledgments

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Ageing gracefully to increase product longevity

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Keywords: product lifetime; graceful ageing; e-waste; accelerated ageing; wear.

Abstract: Longer use and responsible disposal of rapidly discarded consumer electronics would slow material throughput and reduce metal extraction rates and associated environmental impacts. Although longevity is technically achievable, extending product lifetimes is more challenging when devices become 'tired', 'worn' or 'damaged' as these attributes are believed to result in loss of value, dissatisfaction and premature disposal. "*Materials mediate the aging process in a tangible and immediate way*" (Chapman, 2014, p. 141), thus users' sustained appreciation of materials will often determine a product's longevity regardless of physical durability and functional lifespan. This paper presents the findings of a user-centred study which explores tactile and aesthetic responses to new and artificially aged mobile phone cases made from leather, titanium, cork, plastic, rubber, walnut and bamboo. The results indicate that preferences for the materials tested were extremely subjective, and even a single participant was likely to have conflicting requirements for the characteristics of the materials (for example, sleek and shiny yet easy to grip). Participants' preconceptions about the meaning and function of materials in a particular context strongly influenced their responses. The ageing process had no effect on the position of the sample materials in preference order, but the comments provided by participants gave useful insights into the variety of ways that wear and damage can be interpreted by different people for different materials in a particular context.

Introduction

Extraction of metals such as tantalum from coltan ore, essential for the functional components of electronic devices such as mobile phones, has severe negative environmental and social impacts (Moran et al, 2014). These devices are frequently replaced and electronic waste (e-waste) is typically disposed of into UK landfills, incinerated, stored in a redundant state, or shipped to developing countries - very few are effectively recycled (Darby & Obara, 2005; Puckett et al, 2002). To utilise resources more efficiently and reduce e-waste, one approach is to encourage consumers to retain their devices for longer and return them at the end of their life (or before) (Cooper, 1994; van Nes, 1999; Braungart et al, 2007; Chalkley, 2001; Burns, 2010; Park, 2009; Wilhelm, 2012).

To assist in a transition from this current 'throw-away society' towards a circular economy (Great Recovery, 2013), the UK Engineering and Physical Sciences Research Council (*www.epsrc.ac.uk*) funded *Closed Loop Emotionally Valuable E-waste Recovery* project is developing materials for the external enclosure of electronic devices which *age gracefully* (Pye, 1968; Rognoli & Karana, 2014) in an attempt to engender emotional attachment, to motivate continued usage and encourage the return of the internal electronics for upgrade rather than disposal. This will enable the efficient re-use of components and recovery of the valuable, high impact metals from the upgraded electronics.

Reasons for obsolescence can be broadly grouped as technical (new products incorporate technological advances), functional (the product no longer works) and aesthetic (the new product looks more desirable) (Cooper, 2010; Packard, 1967; Slade, 2006). Consumer electronics "*tend to occupy a synthetic and scratch-free world of slick polymers…*" (Chapman, 2014, p.141) with wear and damage to the pristine external enclosure widely considered to contribute to premature replacement of 'tired', 'worn' or 'damaged' devices (Odom & Pierce, 2009; Odom et al, 2009; Fisher, 2004; Maffei & Fisher, 2013). The prominent aesthetic change caused by minor wear and damage to pristine enclosures, combined with incremental upgrades in hardware and regular tweaks to styling, all contribute to the rapid turnover of these devices. This research focuses on addressing aesthetic obsolescence, which consists of two main components: 'ageing' and 'style'. 'Style' is how the product looks compared to contemporary designs and fashion, and whether it still exudes prestige (Burns, 2010). We focus on 'ageing' - how a product looks after wear and material degradation (Burns, 2010; van Nes et al., 1999). This study aims to explore users' tactile and aesthetic responses to new and aged portable consumer electronics.

Methodology

The function of an object directly affects the way we perceive the materials from which it is made (Ashby and Johnson, 2002; Karana & Hekkert, 2010a & 2010b). Yet few studies exploring users' response to materials focus on individual products - many utilize small swatches of material devoid of context (e.g. Wongsriruksa et al 2012; Barnes et al, 2004). For this study, mobile phone cases made from a range of materials have been used as a rapid, cost effective method of allowing people to interact with the same object enclosed in different materials. Cases made from bamboo, walnut, cork, leather, titanium, plastic and rubber were used (Figure 1). The materials were chosen to include man-made materials currently used for mobile phone exteriors (titanium, plastic and rubber), and a range of natural materials (bamboo, walnut, cork and leather) to elicit people's responses to materials which are unexpected in this context, and to explore the different response to wear and ageing of 'shiny' man-made materials and textured, variable natural materials. One set remained in pristine, new condition, and the other set was artificially aged (Figure 1 & 2).

Artificial ageing

Product testing of electronic devices by manufacturers typically focuses on avoidance of functional failure, not gradual wear and longevity, and there are no published methods or standards for accelerated wear testing for this type of product. We have therefore developed test methods for accelerated ageing of consumer electronics based on the types of wear experienced in use and manufacturers' videos of their durability testing (link to video: https://www.youtube.com/watch?v=HicdXV_47V8). We have divided the wide spectrum of possible degradation mechanisms into two processes**:**

1. Wear - analogous to careful use and handling, and carrying in a pocket or case, which will gradually polish the material over time. To accelerate this form of wear a handheld polisher was used with different grades of polishing disc for different materials.

Figure 1. Mobile phone cases used in the study. New (top) and after gentle artificial ageing (bottom). Despite careful use of diffuse lighting the shiny new rubber (top right) shows reflections.

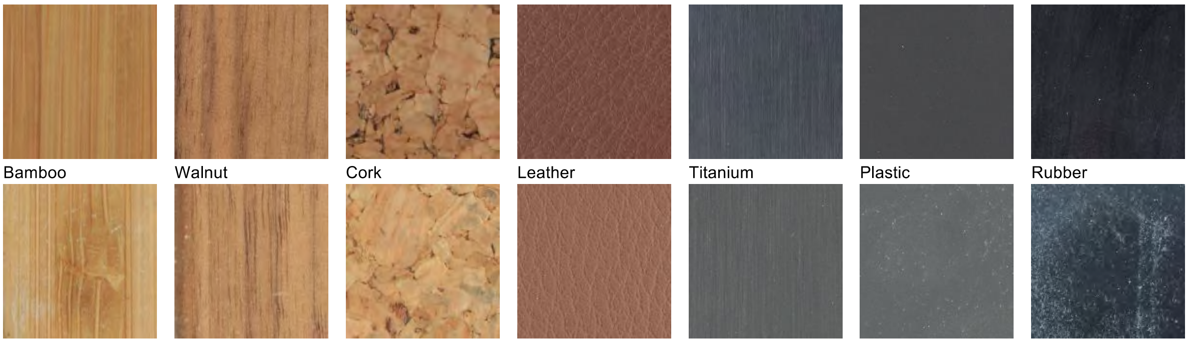


Figure 2. Mobile phone cases used in the study, 20mm x 20mm detail. New (top) and after gentle artificial ageing (bottom).

2. Damage - to simulate less careful use and storage, such as carrying the phone in a pocket with keys or dropping on a rough surface. The mobile phone is fixed to the side of an inclined rotating cylinder, and a selection of keys and coins are placed in the cylinder (Figure 3). The number of revolutions of the cylinder is used to control the severity of the damage.

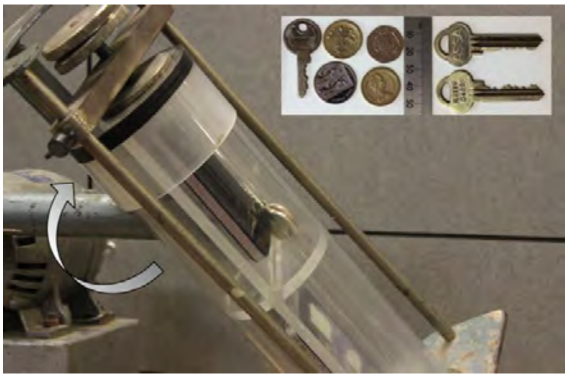


Figure 3. Test set-up for accelerated ageing. Mobile phone cases are mounted on dummy phones within an acrylic cylinder with a selection of keys and coins which are free to move. Rotation of the cylinder results in impact between the keys and coins and phone case causing a gradual build-up of damage to the material surface.

User study

Twelve participants aged 18-25 were recruited from the Loughborough University populous. Semantic differential scales were employed alongside open-ended, discursive questions in a semi-structured interview format. The semantic differential scale, pioneered by Osgood et al (1957), is a scale with bipolar word pairs at each end. A participant is provided with a concept or object and asked to place a mark on the scale which best describes their feelings towards the stimulus (Martin et al., 2012). This method has been used extensively within similar materials studies (e.g., Sakuragawa et. al 2008; Koga & Iwazaki, 2013; Chen et. al, 2009).

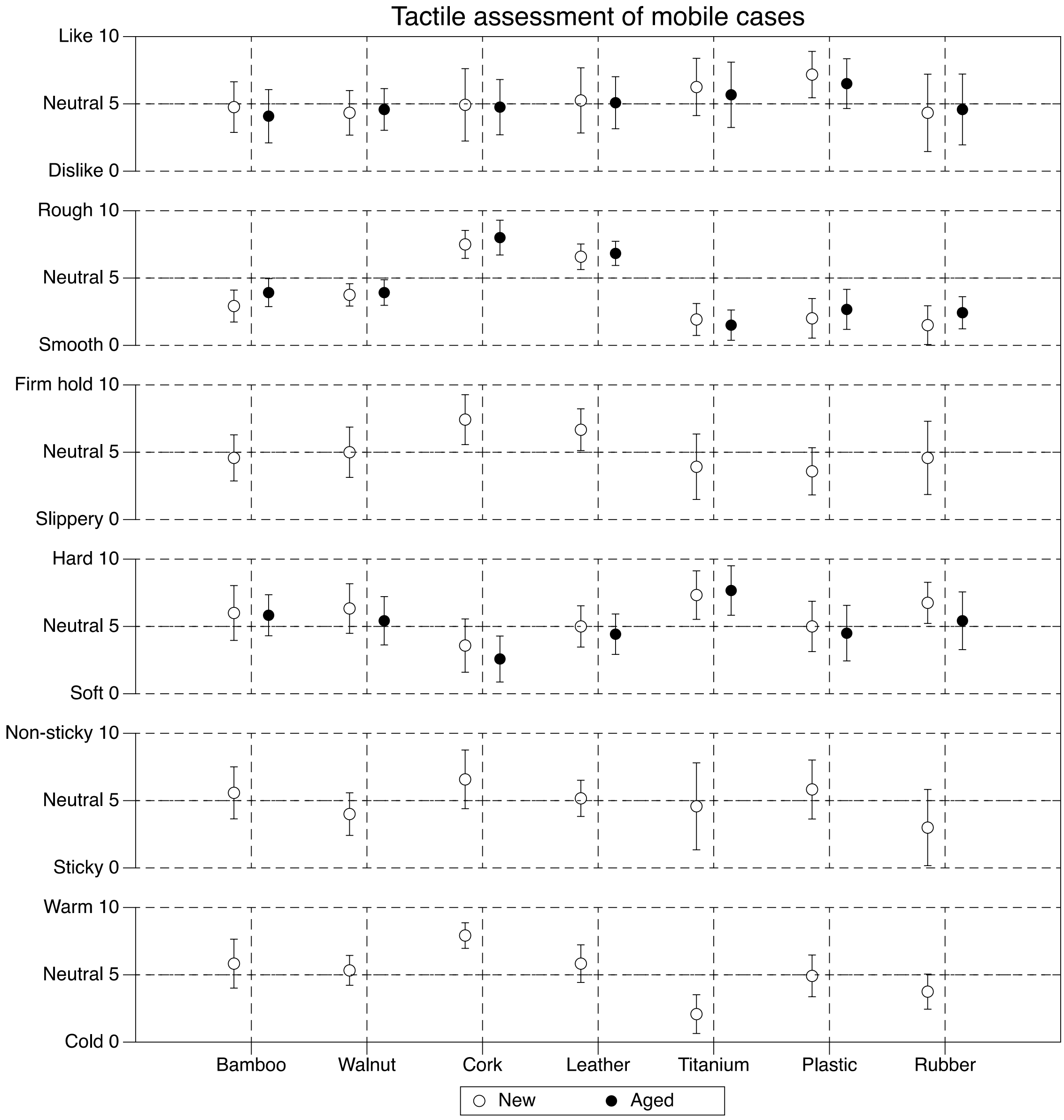
The study was conducted in two parts, in the first part the new sample materials were presented to the participants, the aged sample materials were then presented in part two. Each part comprised of two stages: In stage 1 the participants were blindfolded and each of the seven sample materials was placed in front of them for tactile evaluation. This is common practice in other comparable studies (e.g. Chen et al, 2009) as it provides a response to the material without preconceptions based on the type of material. In stage 2 the blindfold was removed from the participant for visual assessment of the samples.

Results

Results are presented for blindfolded (tactile) responses and seen (visual + tactile) assessment of the new and aged cases (Figure 4). Excerpts from the semi-structured interviews are presented for each material in turn:

Bamboo. Five participants mentioned how large or "*chunky/clunky*" the sample was after seeing the bamboo case. One described it as "*quite bulky and I don't associate wood with technology*". Opinion was divided though: "*I like the wood finish and it's quite light and not dreary like these ones; it felt quite slippery and clunky before, but when I look at it, it doesn't look so clunky",* and *"now I know that these [walnut and bamboo] are the wooden ones I can start to feel the grain when I can't see them*". Although the mean 'dislike-like' rating did not change between the new and aged sample materials, the qualitative comments revealed some changes in opinion following the ageing process: "*the laminate layer is showing it looks a bit cheaper than it did before*", "*its aged the worst… it would be quite easy to crack; it's all worn the colour is disappearing*".

Walnut. When blindfolded the participants ranked walnut as one of the least favourite materials with a mean 'dislike-like' score of 4.3. When able to see the material this increased to 5.0, elevating the sample from sixth to fourth. Six participants mentioned the size of the sample stating that it was 'chunky' or 'clunky', with three finding this to be a positive quality giving 'solidity' or 'heft' to the product and providing protection, and the other three finding it to be too large.



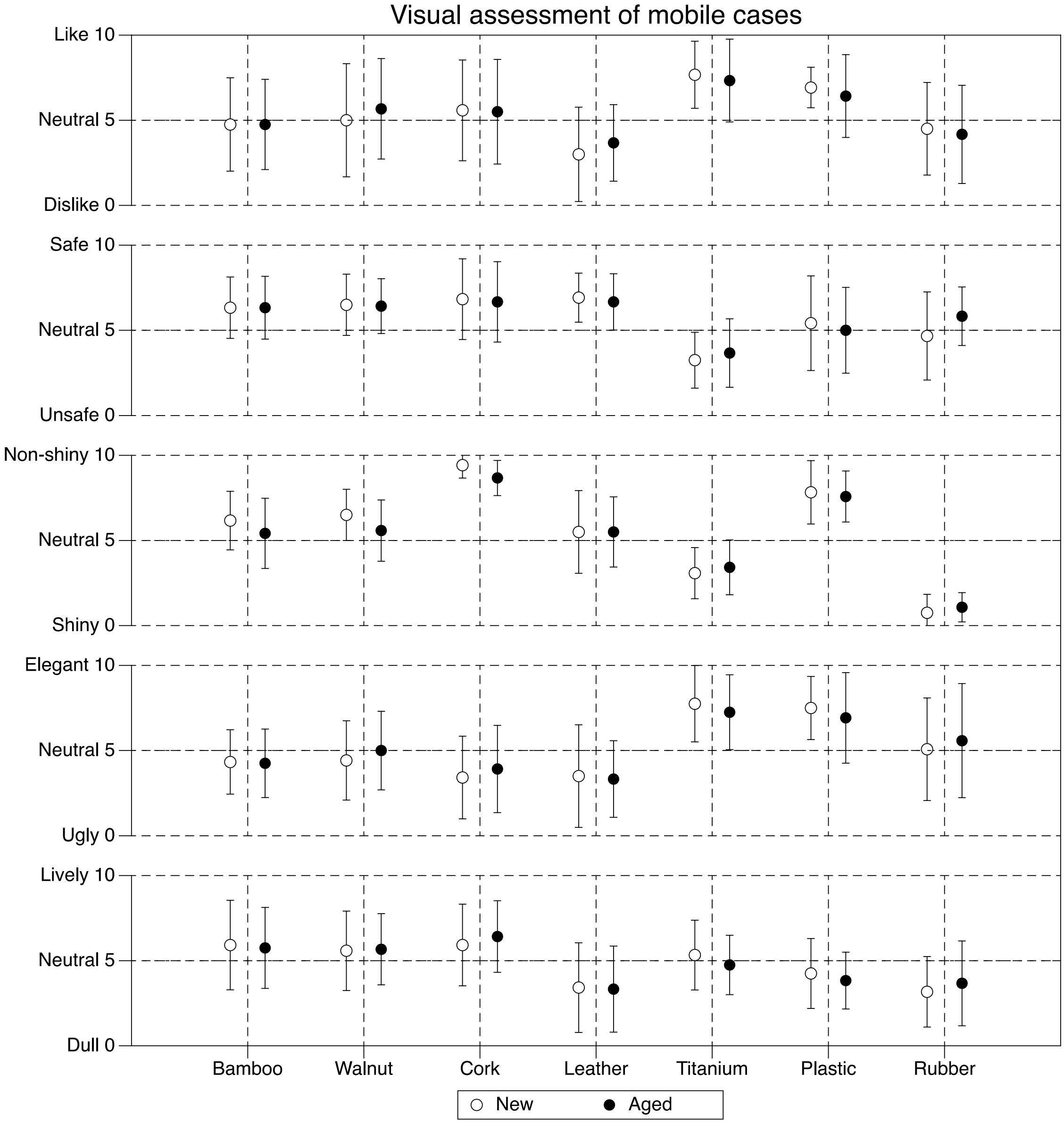


Figure 4. Results from tactile and visual assessment of new and artificially aged mobile phone cases. Circles represent average response, error bars represent plus/minus one standard deviation. A pilot study showed that repeating the word pairs 'Cold – Warm', 'Sticky – Non sticky' and 'Slippery – Firm hold' with the aged sample materials was not necessary as the aging process had no effect on these attributes.

Opinions differed greatly on whether wood is an appropriate material to be used with technology such as a mobile phone. Positive comments included "Wood is traditionally used in well-made hand crafted furniture, gives high quality impression" and "[I] like the solidity it has and the touch, and aesthetically it's quite traditional but not out-dated, timeless". In stark contrast, one participant observed: "I don't associate wood with technology. It feels like building material and not something I want to take out of my handbag". Four participants commented on the effects of the ageing process on the wood, again opinion was divided with one describing it as "dying or broken" whereas another stated that the scuffs and marks gave it "personality" or "character".

Cork. Participants had differing views on the texture of the material: "I don't like textured back, like a feeling of smooth"; "feels like it's coated in textured wallpaper"; "edges are sharp"; "doesn't feel like it would protect the phone"; "feels more flimsy". In complete contrast three participants rated the cork sample as their favourite with each participant mentioning that they liked the texture of the sample: “Nice quality texture, airy, not the most expensive, secure, sturdy, nice to hold”.

When participants were able to see the new sample, two participants significantly increased their rating from two to seven and 10 respectively. One of these participants “thought it was leather” and had therefore given it a low rating, and he now liked the texture of the sample but “only because I know what it looks like now”. This highlights a fascinating interplay of preconceptions about materials with tactile and aesthetic response. Three of the five participants that mentioned cork rated it as their favourite sample, two of whom mentioned cork as being a more “green” or “sustainable” material. Three mentioned how the cork sample was “unique” or “different”. Opinion was also divided about the effect of the ageing process, with views varying from “looks worse now, it’s a lot darker and grubbier” to saying that it had “aged traditionally” and “wouldn’t show scratches much”.

Leather. When blindfolded two participants mentioned the improved grip the leather sample offered as a reason for liking it, with another mentioning that the sample had a different surface texture and was therefore discernable from other electronic devices. The mean blindfolded ‘dislike-like’ rating for the leather sample was 5.3, which was third highest behind plastic and titanium. In stark contrast, when able to see the sample the mean rating reduced to 3.0, with six of the 12 participants rating the leather sample as their least favourite. This was the biggest change from blindfolded to seen out of all of the materials, with a variety of reasons which combine aesthetics with material associations: “reminds me of my Grandma’s purse, not really cool”, “it looks old fashioned but not in a rustic and quirky way like the cork. It reminds me of old men’s suitcases”, “I don’t like the animal print texture...it doesn’t have good connotations” and “seeing it you know it was carved off a cow”.

Following ageing, one participant rated the leather sample as their favourite: “it feels slightly less rough, smoother but not too smooth”. The mean ‘dislike-like’ rating increased slightly from 3.0 to 3.7 following the ageing process. There is no explanation for this in the qualitative data, however other materials were rated lower following ageing, so leather may have improved relatively because it changed little with the ageing process.

Titanium. When participants were blindfolded the new titanium sample had a mean ‘dislike-like’ rating of 6.3, which increased to 7.7 when seen, making it the best liked material. Reasons for liking titanium included “a high quality finish”, “simple”, “strong”, “sleek” and “glossy”. The smooth finish was not universally liked though, with one participant concerned that “it feels slippy and I wouldn’t want it because I think I’d drop it”, raising a common tension between aesthetic appeal and practicality. There were also mixed views on the cold feel of the metal, with one participant giving it as a reason to dislike the material, while another said “cold is reassuring, tech usually warms up and the cold touch is good”. The mean ‘dislike-like’ score for the aged sample dropped to 5.7 when blindfolded and 7.3 when seen. Participants showed differing levels of sensitivity to the changes caused by the gentle ageing process: “this looks more scratched and more faded towards the bottom, it doesn’t look as new. It looks dirty and scratched up” contrasting with “you can’t tell it’s been aged, it’s still really sleek”. Even when aged the titanium remained the most liked of the materials.

Plastic. Six participants liked the “smooth” or “soft” texture of the sample, with five rating plastic as their favourite, explaining that it: “feels quite secure”, “feels quite good quality”, “feels lighter and smaller”, “feels neat and clean”. When blindfolded, the plastic sample had the highest mean ‘dislike-like’ rating of all the sample materials with a value of 7.2. Following the gentle ageing process, the ‘dislike-like’ rating reduced to 6.4 when seen, which concurs with previous observations about the deterioration of the ‘temporary shininess’ of plastic products leading to dissatisfaction.

Rubber. When blindfolded and assessing the new sample four participants mentioned that they disliked the sample because of its “sticky” or “slippery” texture. The mean ‘dislike-like’ score for the rubber when blindfolded was 4.3, making it the least liked material. However, two of the participants rated rubber as their favourite material: “a lot grippier in the hand, harder to slide out of your hand and drop… it feels nice”, “nice texture to it but I don’t like how it’s sticky but I like how it is smooth”. The aged rubber was even less popular: “It’s a lot more smudgy than before", "this one's supposed to be sleek so the ageing affects that", "I don't like this one anymore as it looks more shabby and cheap and you can see the fingerprints on it which is not something you want".

Conclusions

The most striking observation across all aspects of the study were the diverse and contrasting views of the participants, with stark differences between participants, and conflicting desires of a single participant (e.g. sleek, shiny yet easy to grip). This makes it vital to not simply consider the average response to each word pair, but to consider the range of responses and the more insightful interview responses.

It is clear that participants' opinions of the materials are shaped by a combination of factors: tactile response, aesthetic judgement, preconceived feelings about each material (regardless of context), and preconceptions about which materials they expect to see in the context of a mobile phone.

With respect to the 'aged' versus 'new' material perceptions, the ageing process had no effect on the position of the sample materials in preference order, but participants frequently described changes in their feelings towards the materials after gentle ageing. This study does show that moderate wear does not result in unduly negative responses, and that people are quite tolerant of some 'wear and tear' and change to the material surface. A further study will repeat this method with 'severely aged' material samples to ascertain how more obvious ageing and material degradation affects participants' responses.

This study captured the participants' immediate, visceral response to the materials, which may be very different to their feelings towards materials and objects that they have owned and interacted with for a period of time. This is particularly true of wear and damage, which may be interpreted very differently depending when it happens: a scratch caused by dropping a new phone is different to a gradual build-up of wear, or a scratch caused by an interesting event in the owner's life (Odom & Pierce, 2009). A longitudinal study using functional prototypes would be required to explore the influence of time and use on attitudes to materials in context.

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Can global craft and artisanship be the future of luxury fashion?

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Keywords: artisanship; global craft; tradition; heritage; luxury.

Abstract: Why is current global craft and artisanship undervalued, while historic global crafts are highly sought after and collected? Why is there such a perceived gulf in the valuing of the skill sets of European artisans and global artisans? The aim of my research is to explore how global artisanship can be re-contextualized and valued through the partnership of tradition and sophisticated design. The partnering of design and craft can honor and value the tradition, and history of the craft, the context, and the people, while simultaneously re-contextualizing it, and re-valuing the artisanal work through cutting edge, sophisticated design.

The need for companies to embrace sustainable development and ethical business practices, combined with the continued loss of traditional hand crafted techniques, potentially positions global craft as the new luxury. Culture, history and heritage, are priceless, and the authenticity of products made with heritage skill sets are a means of reinvigorating the over exposed branded luxury fashion market. The time has passed when a designer could dip into another culture for inspiration, and then produce their designs without recompense to the community that inspired their work. Designers can no longer in good conscience raid the cultural and historic heritage of others, without partnering with those communities and repaying that debt in equal value.

In a globalized, branded world, the true luxury of the future is handcrafted, indigenous and heritage crafts, re-interpreted into high-end fashion.

Introduction

Contemporary global craft and artisanship from developing countries is generally undervalued, relegated to touristic keepsakes, irrelevant of the history, culture and craft that went into its production. While hand crafted historic artefacts from the same location are highly sought after, valued and collected, and European artisanship is considered the pinnacle of contemporary luxury. Why is there such a perceived gulf in the valuing of the skill sets of European craftsmen and global artisans? Is it possible to re-contextualize and revalue global artisanship through the partnership of tradition and sophisticated design, to reposition it as contemporary luxury fashion?

Global craft

The previous statements may seem obvious and perhaps overly simplistic, but are never the less intrinsically true. There are of course many factors leading to the devaluing of global craft, some historic, some current; socio, economic, cultural and racial, to name just a few. I am not a cultural anthropologist, I am never the less, a keen observer of culture at the intersection of craftsmanship, with many years of field experience working with women's cooperatives, and the creative industries in the developing world. Much of that experience has proven to me, that the intrinsic difference between European and global craftsmanship is access to quality materials, the logistical facilitation of sourcing and production, a true understanding of the Western luxury aesthetic, and access to markets. All of which can be overcome with committed partnerships that bridge the knowledge gap of the artisans to the global marketplace. To accomplish this requires years of commitment, with no major financial outcome of massive profits, so why go to the trouble? The answer to that is clear; it's the same as it is for European Haute Couture, It is about keeping alive know-how. For global craft, it is to save traditions in danger of being lost, and in doing so, sustaining communities and cultural heritage.

The need for companies to embrace sustainable development and ethical business practices, combined with the continued loss of traditional hand crafted techniques, potentially positions global craft as the new luxury. Culture, history and heritage, are priceless, and the authenticity of products made with heritage skill sets are a means of reinvigorating the over exposed branded luxury fashion market at a time when its authenticity is being questioned. The global expansion and democratization of luxury goods to make them accessible to the middle market may have pleased stockholders, but has also led to the replacement of individual craftsmanship with assembly-line production.

Despite their evident commercial success, one question has plagued the luxury goods sector for some time now: to what extent can a luxury brand grow and thrive before damaging its sense of luxury? The question was answered by Dana Thomas in her book Deluxe: has luxury lost its lustre (2007). With very few exceptions, European luxury continues to tell the story of its hand crafted, French or Italian artisanship, while simultaneously outsourcing to developing nations. A fact that has not gone unnoticed by many, and has undermined luxury's perceived value.

Luxury relies on limitations of production and the value of rarity and scarcity, something lost with the democratization of luxury, and the introduction of fashionable lower-priced accessories, and exacerbated with the expansion of retail reach to a vast global network of stores. In contrast, traditional artisanship is by default entirely authentic, and offers something special, in the same way as haute couture, where garments are considered as investments on an economic and emotional level, by default extending the product lifetime.

Global artisanship can be completely re-contextualized and re-valued through the partnership of tradition and sophisticated design. The partnering of design and craft can honor and value the tradition and history of the craft, the context, and the people, while simultaneously re-contextualizing it, and re-valuing the artisanal work through cutting edge, sophisticated design. Few designers have managed this delicate balance; many are in the emerging designer space, with very few notable exceptions, Donna Karan's Urban Zen probably being foremost. Karan's Haitian Artisan Project spans a range of expressions, materials and products, all produced by Haitian artisans, using locally sourced materials. It honors the creative role of the artisan, and partners with Karan's understanding of a sophisticated Western aesthetic. Donna Karan has created a model at the intersection of business, craftsmanship and philanthropy that serves as the base of what has become known as the Soulful Economy. Most of the items produced are housewares, with some jewellery, and accessories, but no clothing. Never the less, textiles form the basis of much of the craft tradition in many cultures around the world, making the transition to fashion a natural extension.

This type of partnership is quite rare, most fall into one of two models: the sustainable development model which, focuses on training new skills to a disadvantaged populace as a means of said individuals gaining self-sufficiency, and raising their standard of living. The second developmental aid model focuses on facilitating market access for traditional crafts, thereby focusing on craftsmanship, but with little design intervention or collaboration. I consider Donna Karan's soulful economy a third model, one that combines and builds on the best of both, and the model that has the greatest likelihood of acceptance in the luxury fashion marketplace.

Sustainable Development

There are a number of current designer collaborations with global artisans, the vast majority however focus on the developmental component of their undertakings, a reflection of their developmental aid roots, underplaying local craft and tradition, instead introducing new skills, not working with existing ones. All too often this results in the over simplification of traditional cultural symbols, reinterpreted with a Western aesthetic, process and product. Clearly there is enormous value to this model, it does after all bring self-sufficiency and sustainable development to disadvantaged groups, but it does nothing to retain and honor existing traditions and crafts, that isn't after all its purpose.

Vivienne Westwood's African bag collection is a good example of this type of philanthropy. The collection is produced in collaboration with the Ethical Fashion Initiative, an organization, which supports the work of thousands of female micro-producers from marginalized African communities. Designs are produced from recycled canvas, upcycled roadside banners, leather off-cuts, and recycled brass, and produced in one of Nairobi's largest slums. The mission to upcycle locally discarded materials, combined with developmental aid, is clearly an exceptionally worthy undertaking, but never the less, negates the rich cultural heritage and craftsmanship of the region. Although the most recent collection does in fact feature hard wired beaded bags, not dissimilar in technique to the Maasai beaded collars.

EDUN is likely one of the best-known global brands in this space, founded by Ali Hewson and Bono in 2005. EDUN's entire raison d'etre is to promote trade in Africa through sourcing and production. Edun currently manufactures 85% of the collection in Africa, and aims to produce 100% by 2020. The collection is the epitome of a contemporary Western fashion brand, with no aesthetic inkling that the basis of the business is African trade development. Until quite recently the brand has used African settings and imagery as part of the branding message through PR, but clothing has been quintessentially Western in aesthetic. In recent seasons however, Creative Director Danielle Sherman has included a small number of artisan collaborations with African craftspeople such as Penny Winter, URU and Moussa Albaka, all accessories or jewellery designers based in Africa.

While the other brands cited already produce their own fashion collection, and work with global artisans to complement their own line through the creation of accessories and jewellery, Edun produces a full apparel collection in the developing world, with non-traditional skills, to produce the finished product. This is the "teach a man to fish" method of sustainable development, an enlightened outgrowth of the charity model, and based around the concept that if "you give a man a fish, you feed him for a day, but if you teach a man to fish, you feed him for a lifetime."

Developmental Aid

The second model of developmental aid comes through a large number of NGO's that do work with traditional craft, but who's lack of design intervention in the final product, too often results in an undervalued global craft product, that cannot gain traction in a sophisticated luxury market; ultimately the market best placed to truly appreciate artisanship and craft, but which, requires a sophisticated end product to justify the real cost. This model is one step up from local individual artisans selling traditional crafts to tourist markets in neighboring towns and cities, the intrinsic difference being access to consumer markets, with the NGO's ability to access global markets, and their understanding of marketing, sales and Ecommerce. This type of work is inevitably at the lower end of the market, appealing to a low to mid-market customer, and epitomized by Ecommerce sites such as Global Girlfriend, and Ten Thousand Villages.

Stacey Edgar created Global Girlfriend in 2003, as a means to support women worldwide in gaining economic security, by providing expanded market access to women producing handcrafted products. Ultimately, the greatest benefit of undertakings of this type is greater market access, most often through Ecommerce sites, allowing artisans access to a wider marketplace to sell their goods, while ensuring fair trade wages and practices for the artisans. Most organizations in this space, work with local NGO's that provide access to education, health care and training for the artisans themselves. While artisans and products are selected to showcase their work through the website, the overall understanding of a luxury aesthetic is lacking, coming from a philanthropic and charity perspective, rather than a fashion one.

Similarly, Ten Thousand Villages offers a range of handmade gifts, jewellery and home decor made by artisans in Asia, Africa, Latin America and the Middle East. A member of the World Fair Trade Organization, Ten Thousand Villages seeks to establish sustainable markets for handmade products in the West. Sales help to fund access to food, education, health care and housing for the artisans themselves. The mission of Ten Thousand Villages is emblematic of this type of sustainable development, "to create opportunities for artisans in developing countries to earn income by bringing their products and stories to our markets through long-term fair trading relationships."

Both of the previous model types either fail to value tradition, culture and craft, through the lack of inclusion of it in the products developed, or alternatively value it to the exclusion of Western concepts of quality control and design aesthetic. The first model allows for access to the luxury market through a Western high fashion aesthetic, and the exclusion of local tradition and craft, while the second model excludes access to the same luxury marketplace due to a complete lack of a Western high fashion aesthetic. Few have yet to achieve the careful balance of contemporary design, artisanship and tradition that values each in equal measure, though some have come close.

Design and Craftsmanship

The final examples are of designers working with traditional techniques and craftsmanship, honouring the cultural aspects of their work, and collaborating with the artisans to produce clothing or accessories that are a hybrid of tradition produced to a European standard of quality, while appealing to a Western luxury aesthetic. Inevitably many of those achieving this careful balance, are small, independent, emerging designers.

Swati Kalsi is an Indian textile and fashion designer, who has worked with handcrafted textiles for over a decade. Credited with bringing contemporary relevance to time honoured, handcrafted, artisanal textiles, Kalsi helps to support artisanal hand craft, and preserve ancient and traditional techniques, by engaging with artisans in an interactive creative processes, to create distinct pieces of work on the edge of design, craft and art. Kalsi's process is based on an intriguing creative give and take that incorporates inconceivable twists and turns, which result in a timeless, understated elegant collection. She has been credited with being at the forefront of a craft revival in India, as well as for innovation in textiles.

Finally, designer Angel Chang, crafts a womenswear collection using the traditional hand woven textiles of the indigenous Miao and Dong ethnic minorities in Guizhou Province, China. Working closely with the artisans of Dimen village, Chang is trying to preserve these ancient techniques by helping to gain recognition for their craft in the international marketplace. Chang is eager to communicate the breadth of ethnic diversity within China to the outside world. The history, mythology and culture of which, is expressed through dress and textiles, acting as the oral history of the community. As with many global textile traditions, that of the Miao and Dong is in danger of dying out, with the young not interested in the old ways. Never the less, Chang is managing to train a new generation of artisans, and keep the tradition alive through the ability to generate a reasonable income from the craftwork, by incorporating it into her collection.

In both these cases the historic and cultural connection to the development of luxury products made through traditional craftsmanship strengthens "*the appreciation and attachment towards a garment*". In the same way that haute couture once did, "*such garments can… be considered as investments on economic as well as on emotional levels*." Hermes, one of the few luxury brands that still produce in the traditional hand crafted method in its traditional home in France, are a testament to the longevity and value of true craftsmanship. Many of Hermès handbag designs "*have been around for almost a century, and are coveted not because they are in fashion, but because they never go out of fashion.*" According to Dana Thomas, "*to see how an Hermes bag is made is to understand* what luxury once was and which it is no longer" (2007). Global artisanship, craftsmanship and heritage craft still embodies the purest sense of integrity through workmanship, constituting the only real opportunity for the luxury industry to regain its lustre.

Conclusions

Cleary there is no one size fits all response to sustainable fashion, and there is so much work to be done, and there is room for many different approaches. This is an ongoing conversation, with many different voices and perspectives, as it should be, to develop a diverse, supportive and sustainable fashion industry. Clearly there is a move being made by trade not aid models of sustainable development to integrate at least a portion of local tradition and culture into otherwise contemporary Western collections, whether through partnerships with individual artists and artisans, or building on local aesthetics integrated into a few pieces within the greater collection, as both Edun and Vivienne Westwood have done in their more recent collections.

The challenges of working with traditional skills in the developing world are many. Building a shared understanding of key components a product must embody in order to access the Western luxury market, is vital. A common language has to be built that references quality production, but allows for individual artisanal variations, with much current work based on tradition, inconsistent in quality, and made from modern cheap materials, simply due to access issues. Brands must respect and honour tradition and creation by partnering with artisans, while managing the delicate balance of re-contextualizing craftsmanship to a Western luxury market.

In a world where our material connection to the past is constantly being eroded, where knowledge and know how are being lost because of its inability to compete in an industry obsessed with faster, cheaper, surely the preservation of traditional textiles best chance of survival is through re-contextualization in the luxury fashion market.

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Exploring means to evaluate the viability of human activities and the products needed to support them

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Keywords: obsolescence; nature; value; life cycle analysis; biomimicry.

Abstract: All the life forms on our planet adopt a variety of means to be successful and to survive, yet the human species seems to be powerful enough and persistent enough to possibly cause its own demise. Humans create persistent 'stuff' as a means to undertake the myriad of activities that are part of their diverse daily lives; from the energy and resources required to create the 'products', to the infrastructure to facilitate their use and distribution, and finally to the means to cope with the impact on their obsolescence and ultimate demise. It is these 'products' that is a central concern to this conference as we move from the infinite world thinking that created the core of our current economic planning, to our relatively recently realized concerns over the potential for sustainable growth on our planet.

This paper is a development from the work on obsolescence previously undertaken by the author, which identified viable causes of obsolescence, which would help in the appropriate planning for its ultimate reality. The intent here is to extrapolate from the causes of obsolescence and reflect the findings against the nature of human activities and their associated paraphernalia. The aim is to offer the foundations of a metric that could provide a more viable sense of value to the judgments and methodologies associated with our economic, technical and social activities, particularly when conducting studies in Life Cycle Analysis. Ultimately the author hopes that this work could help establish appropriate lives and lifetimes for the products we create.

Introduction

The primary concern behind the perceived need for Longer Lasting Products is one of dissatisfaction; be it for personal, economic, environmental or social reasons. Interestingly it is reasonably easy to explain and justify such concerns. When people feel dissatisfied that something they own could not continue to function, as a consequence of whatever mode of obsolescence (Technological, Aesthetic, Economic, or Social) there are all manner of reasons to explain it, which may or may not be acceptable (Cooper, 2010). Perhaps the technology was no longer supported, or it broke and the parts are no longer available, or it would be too costly to repair, or even that it was never designed to be repaired at all. Often products look worn out before the end of their expected functional life. Quite frequently people no longer want to do things that way anymore, for whatever reason, and the product is now unusable. The software or the technology has changed, or perhaps the Rubik's cube isn't as popular as it was. The result is dissatisfaction and frustration.

But these conditions are not solely the concern of the user. For the manufacturer there is a real need to be economically viable while technologies, say in electronic communication for example, may be changing almost daily. In contrast, for some products the aesthetics of the day are changing faster than the viable functional life of the product, leading to premature obsolescence or discard; say when a kitchen is renovated leaving functional built-in appliances often to be discarded. We see sofas sitting by the side of the road, too expensive to re-cover, while in many homes and restaurants there are increasing numbers of ashtrays that are no longer used; at least for their original intended purpose.

To help us regulate such activities we often look to Standards for help. However, Standards, such ISO (International Standards Organisation), as with all standards, act passively, responding to events and practices as they unfold, finding it difficult to prevent danger and disaster even in cases resulting from nuclear waste. For the standards governing the life of products there would need to be a dynamic response that would realistically only be possible for the most mature of products; those products that have not changed, and are not expected to change, into the foreseeable future. The stainless steel western dining fork, for example. Here multi-year guarantees can be offered and justified. The material can be guaranteed, and the user, knowing that they are likely to need dining forks long into the future can buy such long life cutlery. But here a significant cause for concern becomes apparent. A fork that looks like a fork, made of reasonably effective stainless steel may also bend and distort unacceptably. Even when there is well founded product logic with a sensible product life, products exist that fail to fulfill a clearly identifiable role. In the case of domestic cutlery, we can encounter all manner of alternatives, ranging from so-called disposable or throwaway cutlery, to lower cost items that are all we think we can afford at the time, or items that are good enough to use but either not valuable enough to steal, say from a cafeteria, or not a great cost if they are. All these alternatives exist alongside long-life, well designed and well-made items that in the worst case are made of single identifiable materials that are easily recyclable should society decide, at some point in the distant future, that we no longer want to eat our food using forks.

Clearly the key to rationalizing product life is not simply to make all products last forever. Antique shops thrive on those objects that are still useful, and where their function is still valued, but with aesthetics that are no longer considered old-fashioned, but timeless; as is the case for many pieces of wood furniture. Less successful, however, are the items that are no longer socially viable; wash boards, carpet beaters, and perhaps in the future, decorative ashtrays; however, for the antique dealer, the rarer the item the higher the price. A price solely dependent on what the public is prepared to pay.

Objects have value because we think they have value and for no other reason. The products we surround ourselves with reflect our activities, our values, and our lifestyles. Clearly we need standards and codes of practice that work in harmony with the needs of industry and the consuming public, but how this is achieved is not simply a matter of making products last arbitrarily say twenty years, or even forever. For the vast majority of products there has to be an appropriate life span. Where there is fast changing technology there will be fast changing products that reflect it. Where there is fashion, then products will become appropriately out of fashion. Where there is a complex infrastructural product, even the domestic kitchen, there will be influences on the life expectancies of its contents. When safety codes change, there will be the need for upgrades or planning for a products acceptance for a number of years.

From personal research it would appear that, in hindsight, the appropriate lifetime of any product can be determined relatively easily. However, the modes of obsolescence identified previously, also make the predictability of the likely life expectancy and its appropriateness of any new product equally possible. This paper will explore how such lifetimes can be predicted and planned for into the future, and the means for identifying critical concerns.

Our environmental awareness

Perhaps it was seeing photographs of the Earth from space in late 1960s, or the oil crisis of 1973, but since that time, just over 40 years, there has been a growing realisation that we live on a finite planet a long way from anything similar, and that from the Industrial Revolution onwards we have had a fairly negative impact on the planet and the precious resources we have taken advantage of for centuries. We now commonly talk of ‘Cradle to Cradle’ thinking rather than the ‘Cradle to Grave’ thinking that still lies behind much of our economic thinking (Braungart and McDonough, 2002). We are currently exploring the means to understand and make judgments on the environmental impacts made during a product’s lifetime. Life Cycle Analysis (LCA) is considered the logical vehicle of choice in this case, by bringing together all of the impacts involved in the existence of any product. This is not an easy road to build, with many companies using LCA as a tool to justify whatever product they want to put on the market by narrowing the scope or boundaries of their analysis; but this is an on-going struggle. Hopefully soon, LCA will carry with it the means to evaluate accurately the impacts and benefits of all our design and manufacturing activities, and the products that result; and this offers a great opportunity.

In the infinite planet that we thought we lived on up to the 1970s, though some would argue that we still think this, any socio-economic equations regarding the validity of any product would be open ended, based on a notion that waste was of little consequence, and that there would always be new sources of energy and resources to find; additionally our Gross National Product (GNP or GDP) was based on activity rather than efficiency.

Now we are increasingly made aware of the limitations of our finite planet, even if too many are not convinced that such concerns are valid. But as we move closer and closer to comprehending and understanding the limitations we have on our resource use and manufacturing activities we need to change the way we go about product planning. In essence we are fast moving to a time when all our equations relating to the valuation of our design, manufacture, use and discard activities will no longer be open-ended. All the factors can now be known, and the social, economic and environmental impacts can be determined. Around the world LCA practitioners are bringing us closer and closer to codes and data that can be more readily integrated into sound international standards and hence approaches to design and development.

This is real progress, however there is one difficult factor still worthy of exploration, and that relates to the determination of our notions of Value.

Value and Maslow's hierarchy of needs

Bruce Archer, formerly of the Royal College of Art in London, was well known for reminding us that things have value because we think they have value, and for no other reason (Cross, 1984). Every antique program on television carries with it the question of 'how much is it worth?' which simply relates to the question of 'how much could I sell it for?' Our valuations are in fact quite variable. Rarity is a common reason for monetary value, but even in the world of antiques we can be fickle. Some antiques can even go out of fashion or even become worth-less as more are discovered. This was the case with the British 'Penny Black' stamp. The value of what was thought to be a very rare stamp has diminished over time as more were found (Holyoake, 2013), while the world of stamp collecting continues to lose its appeal as fewer and fewer people actually post letters.

If we are going to be able to utilize LCA appropriately, then we will have to find ways of evaluating not just the environmental and economic impacts, we must also look to the value of our social activities and the products we use to support them.

Abraham Maslow created a well-known hierarchy of needs associated with how we live our lives (Maslow, 1943) His work indicated the importance of fundamental needs (food, water, shelter etc) and progressively to those needs that allowed us the luxury of self-actualisation. In principle he offered an awareness of the aspects of our lives that we must all struggle to deal with.

We are fortunate in the western world that many of our basic needs are relatively affordable to many, and so we are able live through most steps in his hierarchy. Interestingly we have been so successful that some researchers have taken Maslow's work further, by exploring a more detailed breakdown of our self-actualisation.

This paper postulates that an evaluation of the value, worth and benefit of such needs and attributes is worthy of investigation.

Biomimicry and Rachel Carson

In the 1950s Rachel Carson (1951, 2002) warned of the impact of toxic chemistry on fish and our waterways. There have always been concerns for pollution and cleaning up our mess, but Rachel Carson was warning of damage that was permanently changing life forms and the chemistry of our precious aquifers. Perhaps this was the first time that our wildlife was seen in the larger context, as barometers of the impacts of our industrial activities. Slowly we have taken up the gauntlet thrown down by Rachel Carson, and most recently, the work of Elaine Benyus (1997) has offered us the notion of Biomimicry. The means by which we can learn from, copy, or mimic the sustainable activities found in all parts of Nature, as a means or even basis for all our activities. Recent competitions have identified features of plants and animals that could offer benefits to us all. From the initial realization that spiders produce materials at room temperature using water and other dead insects that are stronger, pound for pound, than Kevlar, and far more environmentally friendlier to dispose of at the end of the web's life.

For the purpose of this paper, Benyus' book offers a hierarchy or guideline adapted from her observations of how Nature works, to help us re-evaluate our activities. Her work suggests:

- that waste should be a resource
- that we should diversify and cooperate to fully use our habitat
- that we should gather and use energy efficiently
- that we should optimize rather than maximize
- that we should use materials sparingly
- that we shouldn't foul our nests
- that we should not draw down on our resources
- that we should remain in balance with the biosphere
- that we should run on information.
- that we should shop locally

This list could now be considered to be a fairly self-evident backdrop to how we should live on our finite planet. It would also seem important to see how this list relates to the work of Maslow, where the suggestions for how we should go about or select our activities, and the products needed to carry them out, could be compared or related to our hierarchy of needs. In simple terms, it would appear to make sense that we should attempt to enable our fundamental needs to be achieved in the most eco-sustainable, natural, way possible. Interestingly, it is in the area of self-actualisation that the comparison could become more beneficial to the challenge of identifying appropriate lives and conditions for our products.

We should remind ourselves that just as things have value because we think they have value, products exist as facilitators of social activities. We need electric drills because we need accurate easily created tubular holes etc etc. Products are a means to an end, and it is the ends that need to be evaluated if we are going to be able to bring to bear any appropriate judgment as to the appropriate, desired and viable expectation of any products life, and, at some initial point, its right to exist at all.

Hierarchy of value of human activities

Over many years the author has attempted to create a hierarchy related to the activities we indulge in on a daily basis in relation to the work of Maslow and Benyus.

This hierarchy begins with similar fundamental concepts and works its way towards the vehicles of self-actualisation and beyond. It begins with the same fundamentals:

- Essential for Survival
- Safety
- Usability
- Convenience
- Comfort
- Luxury
- Decadence
- Dangerous
- Disastrous

It is reasonably obvious that the needs of survival related to healthy air and water, for example, deserve paramount attention. As a next step, having those resources be safe and usable would also seem something of a priority. Moving to ensure that such resources would be convenient would be the next step, and for air and water, the case is easily made. Moving to comfort is a more costly activity, but would be a measure of a successful society.

The issue of luxury is far more difficult. The British chef, Jamie Oliver, considers french fries, or chips, to be a luxury, or better, a treat; very nice to have occasionally, but not healthy or necessarily affordable on a daily basis (Oliver, 2010). So, to add to this list of luxuries, the author offers Champagne; on special occasions it would seem a good idea to celebrate with champagne. And on a larger scale. Every four years it seems to be a good idea to let the best athletes of the world compete against each other. Hence we have the Olympic Games or Football's World Cup. Hopefully not too excessively, but a healthy treat or luxury.

When we go beyond luxury we encounter the notion of decadence, reflecting decay, where activities have profound environmental impacts beyond their benefit. At this point the reader might be interested in seeing how any human activity might be fit into this hierarchy; Fishing, Education, Shopping, Fashion, Heating Products, Domestic Appliances as examples. The author worked with students and found it interesting to see how such activities or needs either, can be related to the hierarchy, or could be related; appropriately or not.

The final steps in the hierarchy are likely self-evident - danger and disaster - and our participation in such activities should be far more difficult to justify. Nuclear weapons, or even resource exploration are obvious areas for further work.

Maslow, nature, and the values of human activity

Rather than attempt a complex definition of Nature, the author looks to use Nature as a reflector of the health of ourselves and our activities on the planet. Simply put, if the natural processes, identified by Benyus, that gave rise to the relatively stable planet that we evolved on are respected and continuous, then we are healthy and good-natured. If we are destructive, unable to clean up our messes, and endangering our eco-systems, biodiversity and the opportunity to live healthily into the future, then we are bad-natured. In this sense the author offers the following parallels in the study of the previously identified hierarchies.
In this brief paper these parallels are not offered as absolutes, but the suggested parallels offer some ‘food for thought’, as we attempt to plot the relative merits of our activities against the eco-sustainability of our shared environment:

- At the primary level Maslow (1967) lists our biological and physical needs; air, food, drink, sex, sleep, and shelter. Nature also looks to survive, and our own activities reflect the similar objectives.
- For Maslow, Nature and our own activities, safety is a next objective.
- Maslow then moves to the challenge of belonging; being part of a family or system that we understand. Nature too looks to the ready availability of what is needed including being part of a family or group or even a supportive location or micro-environment. Human Activities too offer us usability and utility in the products that support our lifestyle goals and activities.
- Maslow then looks to esteem, while Nature looks to stability and the easiness of survival and to flourish, while our human activities move to the needs of convenience and comfort for our products and surroundings.
- Here we then move to what Maslow terms Self-Actualisation. Where Nature tries, and succeeds to be established, even to take-over or dominate, and human activities reflect comfort and luxury (our treats).
- More recently others have started to break down the next steps in Maslow’s self-actualisation, (Schacter et al., 2011). Here Nature can try to take over and change the local habitat for ever. On such occasions it is forced to move into pastures new or even reduce its own population; in some instances becoming threatening and causing endangerment to other species. In parallel, our human activities move towards Decadence (perhaps the option of the very rich and powerful), and on towards danger and disaster.

This brief exploration has not been undertaken here in any great detail. Hopefully the reader can make their own parallels. However, it is postulated that if we are to examine how the products reflected by our human activities should be appropriately related to appropriate lifetimes, then we should perhaps first consider the activities that they are part of.

If we are to consider the validity and appropriate lifetime for any product as part of any activity, then we should link it to a hierarchy related to its impacts; taking us from our basic needs through to healthy survival, and on to the dangers of decadence and beyond.

Doing healthy things in healthy ways

While we would like to think that civilized human behaviour should result in us making healthy decisions about how we live and the products we evolve to help us do so. However, this is clearly not the case, or this conference would not be needed. To help us on the path to the finite world thinking that we need to evolve, we need the development of guidelines, knowledge, education, standards and laws. When we are faced with the many examples of products whose lifetimes dissatisfy us we have two choices. First we can attempt to learn from our mistakes and move forward by telling others the lessons we have learned. The second choice lies in the establishment of laws, standards and practices, and here we must reflect on the nature of our human activities.

In Longer Lasting Products (Cooper, 2010) the author described four useful modes of obsolescence that are identifiable and largely predictable. As was mentioned previously, where there is fast changing technology there will be fast changing products, and predictable technological obsolescence. When long lasting products are predictably discarded due to their short life aesthetics we create an inappropriate in-balance. In a sense the modes of obsolescence described can be seen as identifiers of predictable change, of opportunities, and of potential problems. In such a way, issues such as the availability of replacement parts or upgrades after the cessation of production could be established by law, practice or standards.

However, the nature of the product reflects the nature of the human activity. A simple maxim could be that our goal in living prosperously on our finite planet is simply to adopt a strategy of doing 'healthy things in healthy ways'. As such, undertaking an environmentally unhealthy activity cannot be justified by offering environmentally healthy products to help us do it, and vice versa. In essence, we must explore the causes of our dissatisfaction against a larger backdrop. A backdrop that includes the establishment of rules backed by dynamic equations and models that reflect changing technologies and lifestyles, and establish appropriate lifetimes for the products that support them. Some products will have short lives, and others much longer ones, but all of them should optimize resource use and not contaminate our aquifers and our land when discarded. In Nature, waste is generally food. We must develop somewhat similar practices, where the products that we manufacture should be seen to be part of the same philosophy; as comfortable, safe and convenient as possible, occasionally luxurious, but never decadent, dangerous or disastrous.

Endnote

While the author considers that the four modes of obsolescence identified in Longer Lasting Products are appropriate in the evaluation of the longevity of a product, research undertaken since the publication of the book has identified a further useful mode of obsolescence; that of 'Use'. Some products wear out, others break down, and some offer particles and contaminants that can adversely infiltrate the environment. Examples include chewing gum, toothpaste, tyres, clothing fibres, and cosmetics. While the focus of this conference can be explored using the original four modes, any appropriate planning considering the impacts of the products of our lifestyles should take into consideration this fifth mode of obsolescence to help to establish how we can continue into the future 'doing healthy things in healthy ways'.

Acknowledgments

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The role of consumption in material reduction opportunities: the impact of product lifetime in supplying the UK steel demand

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Keywords: consumption; steel; climate targets; emissions; product lifetime.

Abstract: Most of the products purchased in the UK are manufactured in other countries. As a result, worldwide greenhouse gases (GHG) emissions released to manufacture all products purchased in the UK are significantly higher than the UK territorial emissions. More than one half of global industrial emissions result from the use of steel, cement, paper, plastics, and aluminium. In this paper, the UK consumption of products that embody these five materials is estimated. For steel, which is the most widely used among these five materials, consumption and accumulation patterns are examined across four product categories. The impact of steel product lifetime extension is examined for the UK as one option for material demand reduction at the consumption stage of the supply chain. Different levels of steel product lifetimes are simulated for the UK in 2050 and their impacts are examined in terms of UK steel production, implicit steel imports, and global carbon dioxide emissions. Steel product lifetime extension promotes a reduction in the need for steel imports, by reducing the demand for new steel, which leads to lower carbon dioxide emissions required to supply the UK steel demand. The results demonstrate the criticality of a focus on the consumption stage, since any interventions made towards demand reduction of end-use goods leads to material reduction across the supply chain.

Introduction

In 2007 around 715 Mt of carbon dioxide equivalent were emitted in the UK, as a result of human activities, including industries, transport, electricity generation, and direct household emissions. However, to produce and deliver all goods and services purchased in the UK, around 1 Gt of carbon dioxide emissions have been released worldwide in the same year (HM Government, 2013).

The UK Government is committed to a reduction of 80% of 1990 GHG emissions by 2050 (HM Government, 2011). Such policy targets rely only on GHG emitted within each country's borders, so ignoring the fact that in many developed countries (such as the UK) the emissions associated to purchases are significantly higher than territorial emissions (Hertwich et al., 2009). Since these developed countries are currently the only held to emissions reduction targets, a focus only on territorial emissions may foster industries to be offshored to countries that do not have such targets and therefore not addressing the global problem of carbon emissions.

The magnitude of GHG emissions for which UK purchasing is responsible for highlights the relevance of potential emissions savings resulting from material reduction opportunities in delivering the UK products purchased by UK consumers.

More than a half of worldwide industrial emissions result from the use of only five key materials: steel (which alone accounted for 25% of worldwide industrial emissions in 2005), cement (19%), paper (4%), plastics (4%), and aluminium (3%) (Allwood et al., 2012). These materials are widely used to manufacture products, which are purchased and used worldwide. Any interventions across the supply chain of these materials – from resources to manufactured products – aiming to reducing material use have the potential to deliver significant energy and emissions savings.
Material efficiency opportunities can be identified at any stage of the supply chain of

these materials. Normally, such opportunities are grouped according to the stage of the supply chain where interventions are sought: (i) production, comprising the primary and manufacturing industries; (ii) business-to-business transactions, aiming material reduction at intermediate products, providing the same output of end-use manufactured products; (iii) consumption, aiming material reduction of final purchasing, yet providing the same levels of service delivered to the final user.

In this paper the role of material reduction options at the consumption stage of end-use products is examined, focusing on the impacts of product lifetime extension. We start by quantifying the impact of UK consumption in terms of GHG emissions and material use. From the five key materials listed above, steel is the most widely used in the UK. We therefore examine the use of steel in the UK at the consumption stage of the supply chain, quantifying its uses by product category. The impact of changes in steel product lifetimes in meeting future UK climate targets is analysed.

UK material use and emissions: focus on steel

Manufactured products purchased annually in the UK comprise around 20 Mt of steel, 12 Mt of paper, 11 Mt of cement, 5 Mt of plastics, and 1 Mt of aluminium. Figure to Figure show how these five materials are embodied in different product categories purchased in the UK. Vehicles, buildings and infrastructure are among the products that require the highest shares of several of these materials. Steel is by far the most used material of these five and its use in the UK is examined here in further details.

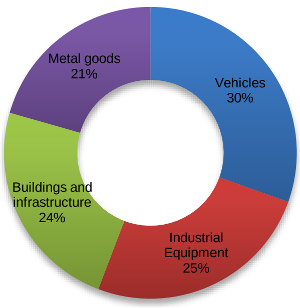

Figure 1. Steel purchased in the UK by product category. Source: ISSB, 2008.

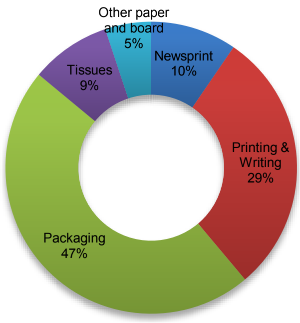

Figure 2. Paper purchased in the UK by product category. Source: CEPI, 2013.

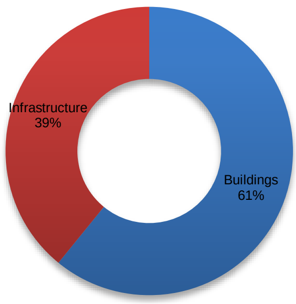

Figure 3. Cement purchased in the UK by product category. Source: CSI, 2011.

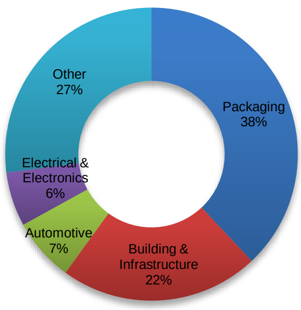

Figure 4. Plastics purchased in the UK by product category. Source: British Plastics Federation, 2014.

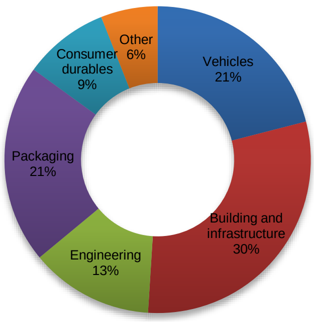

Figure 5. Aluminium purchased in the UK by product category. Source: Dahlström et al., 2004.

Over the last 40 years, 15 Mt of new steel were annually purchased in the UK. UK steel purchases have become increasingly more dependent on imports. Figure shows that the quantity of steel produced in the UK that is subsequently delivered to the UK market has been decreasing and accounting for decreasing shares of the total UK demand.

Crude steel is the first solid stage of steel in a steel mill and the primary output of the most energy - and carbon-intensive iron - and steel - making processes. Crude steel is then subject to further downstream processes at the steel mill where around 6% of it is lost, some of which is recovered as process scrap. Later in the supply chain, when steel products are used to manufacture final goods, on average 19% of steel is lost to fabrication scrap. Therefore to provide the annual average of 15 Mt of steel purchased in the UK, steel industries in the UK and elsewhere need to produce a greater quantity of crude steel to overcome an average of 25% of yield losses across the supply chain. The blue bars in Figure show these figures.

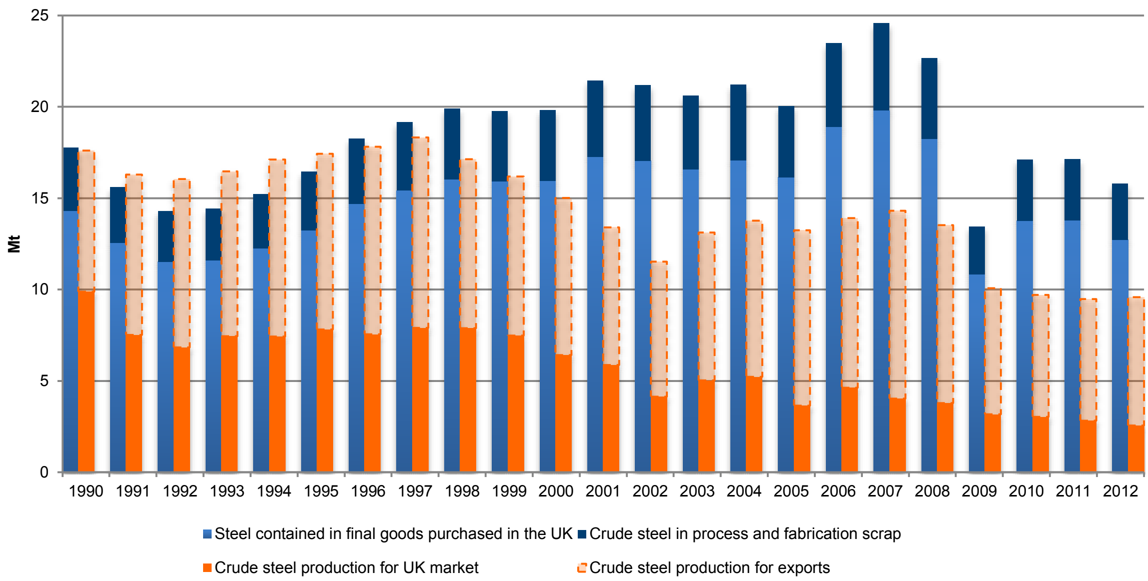

Figure 6. UK steel production and consumption, 1990 – 2012. Blue bars show steel and crude steel required to supply UK consumption. Orange bars show steel production in the UK. Source: ISSB (2008) and authors' calculations.

Current flows and stocks of steel in the UK

In 2007 around 20 Mt of steel was embodied in purchased products in the UK, and only around 13 Mt of end-of-life steel scrap was discarded and removed from use (Dahlström et al., 2006; ISSB, 2008; authors' calculations). This trend has been verified for many years, although with different magnitudes, but on average each year, new steel purchased in the UK exceeds the end-of-life steel discarded. As a result, the stock of steel in use in the UK has been increasing every year. Pauliuk et al. (2013b) have estimated the current in-use stocks of steel for 200 countries, including the UK. Figure shows an estimation of the in-use stock of steel in the UK, as of 2007. Most of the steel currently in use is in buildings and infrastructure, since these products are made using large quantities of steel, their use is pervasive, and they usually last for longer than other product categories.

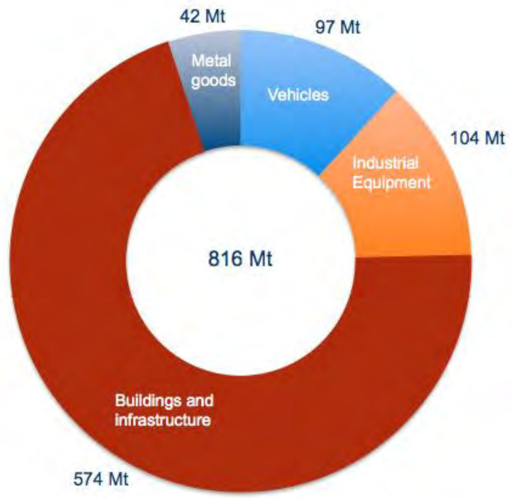

Figure 7. Estimated in-use stock of steel in the UK, 2007. Source: Adapted from Pauliuk et al., 2013b.

In 2007 the in-use stock growth rate was different for each product category. Figure 8 shows an estimate of steel added to the in-use stock and end-of-life steel scrap removed by product category. 63% of steel consumed by buildings and infrastructure was a net addition to the in-use stock in the UK, since 4.7 Mt of new steel were used in this product category and only 1.7 Mt removed as end-of-life scrap from existing buildings and infrastructure. Around 40% of the steel in the UK consumption of vehicles and metal goods was a net addition to the in-use stock of those product categories. However, new steel in industrial equipment almost matched end-of-life steel scrap arising from this product category.

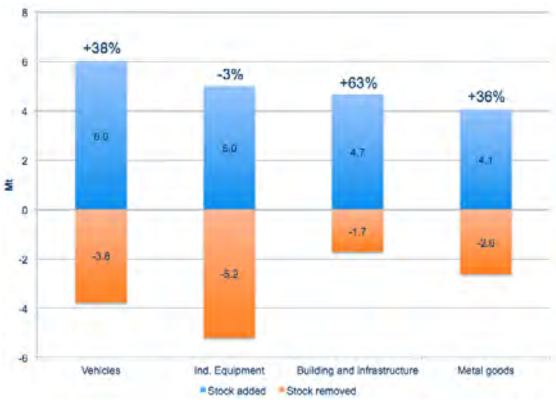

Figure 8. Estimated net additions to the in-use stock of steel in the UK, 2007.

The impact of product lifetimes in meeting future UK climate targets

Pauliuk et al. (2013a) estimate that the in-use stock of steel should reach a saturation level by 2030 at around 13 tonnes per capita in Western European countries. Assuming such stock saturation by the time current UK carbon targets must be fulfilled, the UK steel consumption in 2050 would only be required to maintain the existing in-use stock. Further replacing equal amounts of end-of-life scrap that occur each year, plus new stock required by population growth. Table 1 shows the saturation stock and average steel product lifetimes estimated by Pauliuk et al. (2013a). Under such conditions, and taking into account the population growth rate projected by the ONS (2013), the UK demand for crude steel in 2050 is estimated to be around 32 Mt.

To achieve the emissions reduction commitment, the UK Government has developed the Carbon Plan, setting how the UK should make a transition to a low carbon economy and developing pathways for the structure of the UK energy sector and the energy uses across the different industrial sectors (HM Government, 2011). Each pathway defines the final energy uses by industrial sector and thus their GHG emissions, so the overall impact for the UK would be to meet the target of 80% reduction from 1990 emissions.

Product categories	Saturation stock [tonnes per capita]	Average lifetime [years]
Vehicles	1.3	20
Industrial equipment	0.9	30
Buildings and infrastructure	10.0	75
Metal goods	0.6	15
Total	12.8	

Table 1. Estimated saturated in-use stock of steel and product lifetime. Source: Pauliuk et al., 2013a.

For example, in one pathway of the Carbon Plan (created by the cost-optimisation model MARKAL) (HM Government, 2011), it is estimated that the UK steel industry would be allowed to emit 10 Mt of CO_2 in 2050. Under this scenario, with the current structure of the UK steel industry, it would be possible to produce around 5.5 Mt of crude steel, which is far below the total estimated UK demand (32 Mt). As a result, the minimum amount of crude steel implicit in imports would be 26.5 Mt.

Importing steel either in the form of finished steel products (e.g. sheets, bars, coils) or in the form of manufactured products (e.g. vehicles, equipment) results in significant impacts and carbon emissions due to sea borne transport of heavy shipments (Yellishetty et al., 2010). Furthermore, crude steel production in other countries to supply UK demand for imports also entails carbon emissions related to UK consumption, which are estimated to be around 1.1 t CO_2 / t crude steel in 2050 (Allwood et al., 2010).

Graphs in Figure show the impact of changes in steel product lifetimes from those assumed in

 in UK crude steel production, the required implicit crude steel imports, and worldwide carbon dioxide emissions to supply the UK steel demand. Three alternatives are assessed: extending average lifetimes for all product categories of

 by 20%, by 50%, or decreasing by 20%.

Product lifetime extension may be achieved by fostering reuse and repair of existing products in-use or even by reducing the need of material services. The estimate presented here shows that extending steel products lifetime in 50% can save around 10 Mt CO2 worldwide comparing to the baseline scenario, can decrease the need for steel imports, and can support UK employment in the maintenance and repair industries.

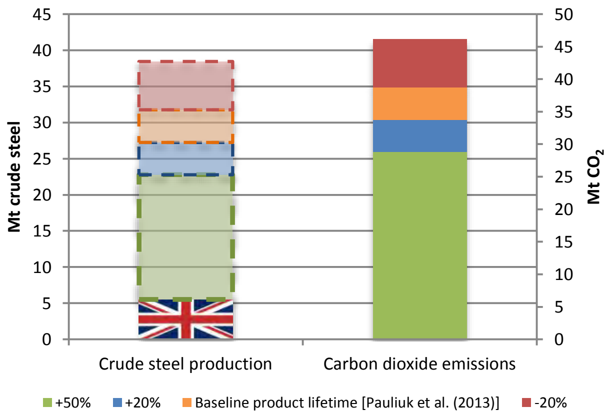

Figure 9. Estimated crude steel production in the UK in 2050, implicit crude steel imports (dashed lines), and worldwide CO_2 emissions for different levels of steel product lifetimes in the UK.

Conclusions

The impact of steel product lifetime extension is twofold: (i) longer product lifetimes result in a reduction of pace of replacement of existing saturated stock, and thus reducing the total UK steel demand and consequently the implicit imports required; (ii) producing smaller annual quantities of steel requires less energy uses and consequently smaller carbon dioxide emissions (both in the UK and in other countries to supply the UK steel demand).

Maintenance of in-use stocks and the reduction of the pace at which they are replaced by new flows of material result in a reduction of the impacts associated to material production. Our results show that steel products lifetime extension can deliver significant global emissions savings as a consequence of decreasing the demand for steel imports.

This example on the impacts of steel products lifetime extension in the UK shows the criticality of a focus on consumption. In the steel industry significant progress is possible either at the production stage (such as process yield improvements) or at the business-to-business transactions (such as improvements of fabrication yields and efficiency of manufacturing processes), although material reduction options at the consumption stage have impacts across the entire supply chain. Material reduction opportunities at the consumption level lead to a reduction in demand for all primary materials used to manufacture end-use products. This shows a particular relevance in the case of steel, whose use is pervasive in the UK and whose production stages are the most energy-intensive processes of material conversion.

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Extending product life by introducing symbolic meaning: an exploration of design strategies to support subjective well-being

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Keywords: symbolic meaning; subjective well-being; personal significance; design strategies; product longevity.

Abstract: Because products are often discarded while still fully functioning, it may be possible to support durability with design that stimulates a more enduring product-owner relationship. This paper is based on the proposition that one promising approach to support such prolonged relevance is by developing products with a higher predisposition for the attribution of happiness-related symbolic meaning. The study was based on a framework with six types of symbolic product meanings: positive relations with others, personal growth, purpose in life, environmental mastery, autonomy, and self-acceptance. In a pre-study, fifty existing symbolically meaningful products were selected based on these six symbolic meanings. In the main study, seven designers and design researchers analysed these fifty products with the aim to uncover underlying design directions. This resulted in sixteen design directions. The directions can act as a source of inspiration to designers when aiming to design for a long-term meaningful product-owner relationship.

Introduction

Many products are disposed of while they are still functioning properly (van Nes, 2010; Bakker, Wang, Huisman & Hollander, 2014). From a sustainability perspective, this is undesirable. For designers, it is interesting to search for ways to persuade consumers to keep and use their products for a longer period of time by designing products with more durable relevance and value for users (Champman, 2005).

Symbolic meaning is found to be an important source of product attachment (Mugge, Schoormans & Schifferstein, 2005; 2008). This vital insight served as the starting point for the present research, which focuses specifically on happiness-related symbolic meaning. If a product symbolizes aspects of a person's happiness, he/she is more likely to keep it, because losing the product implies that the strong symbolic meaning and thus the 'happiness trigger' is lost (Csikszentmihalyi & Rochberg-Halton, 1981; Belk, 1988).

The present study aims to formulate design directions that can help designers develop products with a higher predisposition for the attribution of happiness-related symbolic meaning.

To explore these design directions, we build on the work of Casais, Mugge and Desmet (2015) which describes how people's subjective well-being (i.e., happiness) can be represented in the symbolic meanings of products. Based on Ryff's (1989) model of psychological well-being, the framework proposed six types of happiness-related symbolic meaning in products: 1) the symbolic meaning of *positive relations with others*, found in possessions that represent meaningful affiliations which provide a sense of belongingness (e.g., an heirloom family necklace); 2) the symbolic meaning of *personal growth*, found in possessions that symbolize transitions, acceptance of past experiences, and continued self-development (e.g, a set of military name tags); 3) the symbolic meaning of *purpose in life*, found in possessions that symbolize the individual's goals and aspirations in life (e.g., a parenthood ring); 4) the symbolic meaning of *environmental mastery*, found in possessions that symbolize the individual's ability to master his/her context and build beneficial networks (e.g., a pair of soccer shoes); 5) the symbolic meaning of *autonomy*, found in possessions that symbolize particular ways of living and life choices (e.g., a sewing machine); and 6) the symbolic meaning of *self-acceptance*, found in possessions that symbolize the positive aspects of the individual, promoting a positive self-image (e.g., a stuffed fluffy bunny).

While these six types of happiness-related symbolic meanings can be of use when analysing existing products, they are too abstract to be of direct use in design processes. In this paper we report a qualitative study in which participants were asked to analyse and uncover potential design directions from a set of product examples.

Methodology

Stimuli

To ensure a large variety in symbolically meaningful product examples, an assortment of 100 consumer durables was collected. The main search criterion was to look for products that were in some way open for symbolic meaning attribution, in which the work of Casais et al. (2015) served as a reference. The search was conducted in several well-known design blogs and online magazines such as Dezeen, Design Milk, Domus, Wallpaper, and Core 77. The assortment comprised of products available in the market and product concepts. It contained identifiable elements relating to one or more happiness-related symbolic meanings, either embedded in tangible features or implied in the activities suggested by the product (e.g., reflective activities, storage of memories).
A set of 100 stimuli cards was printed, each card representing one product example. The cards had a dimension of 10 x 5 cm, and contained an image and information about the product (Figure 1). Because the set of 100 cards was too extensive to use in the main study, a pre-selection of the 50 best product examples was made. This selection was done by four experts in Positive Design (i.e., design for subjective well-being) in a one-hour group session. Based on the specialist insights, the most striking and convincing examples were selected. The final selection can be found online at: http://symbolicmeaningresearch.weebly.com/.

Figure 1. Stimuli cards used in the study.

Participants

Seven design researchers and designers with experience in designing products (at least a Bachelor Degree in industrial design) were recruited (see Table 1).

Procedure

To keep the task feasible for the participants, the study was split into two subsequent sessions: categorization and analysis. These two sessions were conducted individually and recorded (video, audio, and photographs). Three days before the first session, the participants received the 50 product cards by email, and were asked to read each card to get acquainted with the product examples.

The first session started with an explanation about the framework of happiness-related symbolic meaning. The participant was asked to read a short summary of each type of meaning, which included examples of symbolically meaningful product stories discussed in Casais et al. (2015).

Following the introduction, the 50 product example cards were provided to the participant. The participant was instructed to divide the product examples over the six types of symbolic meaning in a quick and intuitive way, vocalizing his/her thoughts, and to use post-it notes in the examples that were suitable for multiple meanings.

Participant code	Qualification	Role
DRP01	MSc of Product Design	PhD candidate (Design Theory and Methodology)
DP02	MSc of Industrial Design Engineering (Design for Interaction)	User-centred designer
DRP03	MSc of Industrial Design Engineering (Design for Interaction)	PhD candidate (Positive Design)
DP04	MSc of Industrial Design Engineering (Integrated Product Design)	Industrial designer
DRP05	MSc of Design	PhD candidate (Design for Sustainability)
DP06	Bachelor of Engineering (Industrial Product Design)	Product designer / production assistant
DRP07	MSc of Industrial Design Engineering (Design for Interaction)	PhD candidate (Product Conceptualization and Communication)

Table 1. Summary of the participants (DRP= Design Researcher, DP=Designer).

In the second session, the participant was asked to analyse the categorization and uncover 'design for happiness' directions. Specifically, the participant was instructed to analyse the possible strategies behind the product examples in each group. To help the participant uncover potential design directions, questions were asked that stimulated exploration. For example, by asking why the participant placed a certain product in a category; by asking the participant to consider the designer's perspective and possible approaches that might have been used when designing the product example; or by asking the participant to consider his/her own descriptions from the categorization exercise. Once all groups of products were analysed, the participant combined similar design directions into better defined ones, and selected multiple examples to illustrate them.

Results and Discussion

Each participant took on average 3 hours and 50 minutes to complete both sessions and uncovered 10 to 30 design directions.

Following the procedure of Gioia, Corly and Hamilton (2012), the design directions produced by the participants were analysed in three coding cycles. In each cycle, the researchers looked for similarity in the descriptions provided by the participants (in the post-it notes used in the sessions, complemented by the video and audio recordings), identified labels trying to remain close to the participants' phrasing and intention, and grouped those into clusters. The product examples were used to illustrate each cluster according to the selection made by the participants. This process resulted in 16 design directions (Table 2), each illustrated by a product example. For the purpose of exemplifying design directions from each symbolic meaning, six examples are presented and discussed in this section.

Design direction for positive relations with others

A resulting design direction for the symbolic meaning of positive relations with others is: "Support meaningful affiliations, facilitating the practice of specific belongingness activities." This design direction suggests that by making a belongingness practice easier, a product can increase its value for the user because it makes him/her feel like a part of something bigger. This can be achieved by providing guidance or by simplifying said activity, which encourages the user to be a part of that meaningful affiliation or belief system. For example, the *EL Sajjadah* by SOPDS is a carpet that facilitates the praying ritual by indicating the direction of Mecca through an embedded compass and recreating the atmosphere of a mosque through light and printed patterns (Figure 2).

The desire to form social attachments and to feel inclusion is linked to a fundamental human need for belongingness (Baumeister & Leary, 1995), which can be answered and supported through belongingness activities.

Symbolic meaning	***Design direction***	***Description***	***Product examples***
Positive relations with others	Support meaningful affiliations	Facilitating the practice of specific belongingness activities	El Sajjadah (praying carpet)
	Embody characteristics of a group	Using unique characteristics of users (e.g. culture, profession) to design a representation of a group	El botijo (water colling container)
Personal growth	Support active personal development	Providing a platform for active reflection on lessons learned and future expectations	OWL: On the Wisdom of Life (time capsule)
	Embody personal growth	Providing an adaptable design that can accommodate physical and psychological change	My life urn (memento mori)
	Support acceptance and growth from past experiences	Designing a tangible representation of the passage of time	365 (clock)
	Enhance memories	Offering a positive context or activity to reflect on memories of loved ones	Heirloom (display and recorder)
Purpose in life	Encourage positive change	Providing a external trigger that suggests beneficial activities or behaviours	Blank Wall Clock
	Provide a sense of control	Allowing the user to manage the progress towards personally significant goals, or to eliminate or mitigate obstacles that threaten their fulfilment	Kitchen safe
	Keep track of progress	Providing visual feedback to keep track of progress towards personally significant goals	999 Bottles (water bottle)
Environmental mastery	Improve multi-sensorial communication	Improving communication mediums by translating a message into a sensorial experience, for example by simulating intimate physical behaviours	Elfoid (hybrid cellphone)
	Provide a context for meaningful interaction	Facilitating interaction by making use of the context, or props as an advantage	Family matters (role play toys)
Autonomy	Destigmatize	Focusing on and enhancing the aesthetic qualities of physically enabling products	No country for old men (furniture)
	Design for mindfulness	Slowing down processes or disclosing the mechanisms behind how products work to promote a mindful living	The standard collection (lamp)
	Redirect the user's attention	Designing a product that actively requires attention from the user to mitigate or distract from negative situations	Konnekt (game)
Self-acceptance	Allow shared transformation	Providing tools for user input at aesthetic and functional level, in a permanent or temporary way.	Meaning of time (clock)
	Allow self-expression	Providing a tangible platform to wear, share, or display aspects of identity, personally significant ideas, principles, relationships, etc.	Favourite things (lamp)

Table 2. Table with the resulting design directions illustrated by product examples.

Figure 2. The El Sajjadah by SOPDS. Source: www.sonerozenc.com/product/el-sajjadah.

Design direction for personal growth

An example of a design direction for the symbolic meaning of personal growth is: “Support acceptance and growth from past experiences, designing a tangible representation of the passage of time.” This design direction indicates that a product that is designed to facilitate reflection by providing an overview of past events, moments, and lessons learned can influence the subjective well-being of the user. For example, the *365 Knitting Clock* by Siren Wilhelmsen is a wall clock that represents time by continuously knitting a scarf over the course of one year (Figure 3).

Reflection activities (e.g., journals, meditation) have been shown to improve subjective well-being (Csikszentmihalyi, 1990; Lyubomirsky, 2008). Literature on the topic adds that context influences reflection, and that reflection requires the individual’s active engagement (for a review see Rogers, 2001). Thus, introducing (material) triggers in the environment can facilitate reflective practices. In the given example, the knitting of time allows the user to reflect about the past by allowing him/her to symbolically wear the previous year.

Design direction for purpose in life

For the symbolic meaning of purpose in life, a resulting design direction is: “Encourage positive change, providing an external trigger that suggests beneficial activities or behaviours.” This design direction proposes that a product can be a catalyser which encourages a user into positive actions. As such, a product is able to become more relevant for happiness by symbolizing a desired behavioural change.

Figure 3. The 365 Knitting Clock by Siren Wilhelmsen. Source: www.sirenelisewilhelmsen .com/work.html.

Figure 4. The Blank Wall Clock by Alessi. Source: store.alessi.com.

For example, the *Blank Wall Clock* by Alessi has a blank face and comes with a marker which allows the user to draw or write self-chosen activities or thoughts in each hour (Figure 4). When these align with the achievement of personally meaningful goals, it becomes a source of inspiration for the user. This provides the user with the opportunity to define a feed forward on how an action can be performed by translating the mental image of the goal into a visual focal point that stimulates his/her volition.

Design direction for environmental mastery

A resulting design direction for the symbolic meaning of environmental mastery is: “Improve multi-sensorial communication; improving communication mediums by translating a message into a sensorial experience, for example by simulating intimate physical behaviours.” Communication is an essential aspect of the creation of a suitable context for human flourishing, and this direction incorporates motion and/or haptic elements as a metaphor for intimate human behaviours in order to make impersonal communication mediums more nuanced and rich. In that sense, a symbolic value related to the individual’s ability to connect can be added to products.

Previous research indicated that product-mediated contact can effectively transmit affect, and is more effective when it considers elements of human physicality such as touch and intentionality (Smith & MacLean, 2007; Lenay, 2010). An example of this is the *Elfoid P1*, a hybrid cell phone-robot developed by ATR Hiroshi Ishiguro Laboratory (Figure 5). This concept is a simplified human figure that transmits voice and motion to convey human “presence.”

Figure 5. The Elfoid P1 by ATR Hiroshi Ishiguro Laboratory. Source: www.geminoid.jp/projects/CREST/elfoid.html.

Design direction for autonomy

An example of a resulting design direction for the symbolic meaning of autonomy is: “Design for mindfulness, slowing down processes or disclosing the mechanisms behind how products work to promote a mindful living”. This design direction suggests that unveiling the way a product operates ritualizes its use, adding value and improving the use experience (Fuad-Luke, 2010).

The Standard Table Lamp by Knauf and Brown Studio does not have an on-off switch, but rather is presented in parts that need to be put together to function (Figure 6). The user is required to complete the electric circuit by placing the lamp in a low-voltage copper tower. This approach can contribute to delaying the anticipation of the product's function, by increasing the effort to use it.

Figure 6. The Standard Table Lamp by Knauf and Brown studio. Source: knaufandbrown.com.

Previous research has shown that the exercise of delaying gratification can contribute to self-regulation, an important aspect of subjective well-being (Ryff, 1989; Doer & Baumeister, 2010).

Design direction for self-acceptance

For the symbolic meaning of self-acceptance, an example of a design direction is: “Allow shared transformation, providing tools for user input at aesthetic and functional level, in a permanent or temporary way.” This direction suggests that a product can trigger happiness by gaining symbolic meaning when it is open to aesthetic and functional investment from the user. The transformation of the object can lead, to some extent, to the transformation of its user: Someone that offers time and effort to modify something is also affected by it, for example, by releasing creativity. In addition, an object that is transformed by a person retains marks of intentionality that are as a signature. Accepting the result of such transformation can help the user have a positive look on the self ("I made this and it is beautiful/unique"). One way this design direction could be implemented is through temporary or permanent transformations in a purposefully incomplete product. For example, the *Meaning of Time* by Bomi Kim (Figure 7) is a clock mechanism that invites the user to insert a tangible element in the clock hands, involving him/her in the aesthetics and functionality of the object.

Research supports that unfinished products invite exploration, resulting in enhanced product attachment (Borjesson, 2009; Mugge et al, 2009).

Figure 7. The *Meaning of time* clock by Bomi Kim. Source: http://www.coroflot.com/bfsummer /meaning-of-time.

Conclusions

A product's inability to respond to the user's evolving aspirations (e.g., for technological or aesthetical upgradability) can promote premature discarding, but ultimately, the ending of a product's life is a consumer decision. The challenge resides, therefore, in designing products that support durable user-product relationships (van Nes, 2010) by focusing on durability of meaning and value (Chapman, 2005).

Several publications on the topic of emotional durability have explored the role of symbolic meaning in fostering durable user-product relationships (e.g., Chapman, 2005; van Nes & Cramer, 2005). While offering an important and novel perspective on durability, these explorations have not yet resulted in practical directions that support designers in their attempts to design emotionally durable products. The current study aimed to contribute by taking a step further in developing such design directions as hands-on, yet also malleable to the designer's point of view and interpretation. As such, the set of sixteen design directions are intended as exploratory rather than normative, ideally offering inspiration by displaying a diversity of opportunities to design with symbolic meaning.

In this manuscript, symbolic meaning is addressed as a gateway to enrich and deepen product experiences. Although many of the product examples used in this study are 'boutique products' that are produced in small series, our intention is to generate knowledge that can also be useful for mass-produced products. Ideally, the resulting design directions can help designing higher quality interactions with commodities, which could create differential advantage and stimulate brand loyalty. In the design process, these directions can serve as a source of inspiration to generate more relatable and personally relevant features and interactions, embodying (or facilitating the embodiment) of narratives (and in the effects in product use), with longer and more meaningful product-user relationships. For example, designing products that afford a 'freedom of intervention' allows unique interactions and usage narrations to occur, and opens the possibility for symbolic meaning to evolve during usage. This can strengthen the experience users have with a product, service, brand, etc.

We see at least five research opportunities to further develop and refine the present research: 1) developing and testing different formats of delivering and facilitating the design directions to designers; 2) exploring diverse uses of the directions, such as in setting design goals, idea generation, and product evaluation; 3) testing the effects of the directions (on both user subjective well-being and on product longevity) with longitudinal studies using prototypes that result from the use of the directions; 4) applying the directions in an education context, exploring possibilities and implications of their integration in product or industrial design curricula; 5) exploring the possibilities to apply the directions to other design domains, such as service design.

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Exploring liquid lives and product lifetimes

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Keywords: liquid modernity; mobilities turn; nomadic lifestyles; product durability; product lifetimes.

Abstract: Product lifetimes are an important consideration in the context of sustainability. One way to better manage product lifetimes is to promote product service systems (PSS) that complement and/ or substitute traditional forms of product based consumption. PSS satisfy consumer demand by providing time limited access to products via leasing or renting. Here providers typically own the product component of such offerings and thus producer responsibility is extended over the lifecycle. However, while PSS can be found on business to business markets there is a paucity of such offerings on consumer markets. Opportunities that PSS may provide to improve environmental performance are being lost. PSS literature argues that one of the main obstacles to PSS implementation in such markets is the presence of strong consumer object attachments and that PSS simply do not create sufficient value to displace these. However, consumer culture theory (CCT) research suggests that the bonds between certain consumers (nomadic ones) and their possessions are now far from solid: they are liquid. In such instances, consumers highly prize situational value, instrumental use value and immateriality. In other words, demands that form the rational for and may be met through PSS provision. In this contribution we presented selected data from a case study in which pilot baby care PSS were offered to nomadic consumers. The research suggests that such consumers are amenable to PSS provision and that further research is necessary to explore this proposition.

Introduction

Product lifetimes are an important consideration in the context of sustainability (*cf.* Cooper, 2004). Hence product durability and longevity form the focus of significant threads of sustainable design research. One sustainable design strategy to improve product lifetime management is to encourage the provision and uptake of product service systems (PSS) (Cook et al., 2006). Such innovations can be found on business to business markets, such as the provision of hours of trucking (Stahel, 2006) and business to consumer markets, such as the provision of short term car rental services, e.g. ZipCar (Bardhi et al., 2012). In such instances PSS offerings may substitute or complement traditional product focused consumption, i.e. a PSS may be used instead of or in addition to owning and using a car. PSS have been variously defined (cf. Mont, 2002, p. 139)

“A system of products, services, networks of actors and supporting infrastructure that is developed to be competitive, satisfy customers and be more environmentally sound than traditional business models”.

While PSS are not inherently sustainable, they offer considerable environmental benefits and may form part of the mix of innovations necessary to move society toward more sustainable states (Cook, 2014). The environmental benefits of PSS mainly arise from the opportunity they create for extended product lifetime management and consequently achieve improvements in resource productivity, for example (Cook et al., 2006; Halme et al., 2008):

- If the ownership rights associated with the product element of the PSS are retained by providers then they may manage the costs of provision by specifying more durable and longer lasting products. Also, extended producer responsibility might be achieved if the PSS is provided by the product manufacturer
- A smaller stock of products may be needed to satisfy demand and if customers use

these sequentially, intensity of use increases as does the probability of a higher service yield before the product becomes outdated due to outdated technological characteristics, e.g. fashion.

- PSS providers may also use their competencies to select the appropriate products and ensure the correct use of these.

However, while PSS may offer considerable environmental benefits and are provided on business to business markets, implementation rates are comparatively low in consumer markets (Catulli, 2012). Opportunities that PSS may offer to better manage product lifetimes and improve environmental performance are being lost. Reviews suggest that PSS do not add sufficient value in these contexts, principally as they do not meet consumer demand for control, convenience and the experience of ownership, provided by corresponding products (Tukker, In Press).

*"Consumers simply value owning things and having control over artifacts, issues that seem less relevant in a B2B context" (*Tukker, In Press, p. 130).

However, research in the consumer culture theory (CCT) field suggests that these claims should be unpacked and investigated. For example, the work of Bardhi et al. (2012) suggests that the relationship between material (products) and consumers is changing in some instances: nomadic consumers exhibit and reinforce a liquid relationship to possessions. Here it is suggested that nomadic consumers, or "deterritorialized consumers who engage in serial relocation and frequent short-term international mobility" (Bardhi et al, 2012, p. 510), may favour access to products or experiences for short periods rather than product ownership *(Ibid.)*. Such consumer preferences for access based consumption (Bardhi and Eckhardt, 2012) may be met through PSS provision. Indeed, a window of opportunity to promote PSS in certain consumer markets may be opening. In this contribution, we therefore explore this proposition. The remainder of the paper is structured as follows. In the next section, we consider nomadic consumers and liquid relationship to possessions. In the following section, we present a case study in which pilot baby care PSS have been implemented and a liquid relationship to possessions observed among some participants. In the final section, we present conclusions and suggest further lines of inquiry.

Nomadic lifestyles and a liquid relationship to possessions

Rooted in anthropological investigations of the relationship between the social and material, much of consumer culture theory (CCT) focuses on the role of possessions in the construction of consumer identity (*cf.* Arnould and Thompson, 2005). Classic forms of object attachment highlighted in the field, suggest that consumers form strong and enduring bonds with objects that anchor them to certain places and cultures *(Ibid.)*. Indeed, this classic perspective reinforces the reasoning in the PSS field about why PSS struggle in consumer markets.

In contrast, CCT research has also explored how global nomadism provides a context in which to reexamine these consumer-object relations and identify alternative relationships to the material world that go beyond traditional notions of extended self (Bardhi et al., 2012). Here, global nomadism is characterized as serial relocation, frequent mobility and deterritorialization *(Ibid.)*. Under such conditions, consumers are thought to form situational attachments to objects, appreciate objects primarily for their instrumental use-value and value immaterial or light possessions as well as consumption practices. In other words, rather than exhibit a solid relationship to owned products, a liquid relationship to possessions emerges. Thus acquisition strategies that do not involve the transfer of ownership rights to consumers but access to products and the attainment of outcomes might be preferred by these nomadic consumers. Such access based consumption can be defined as

"transactions that may be market mediated in which no transfer of ownership takes place" (Bardhi and Eckhardt, 2012, p. 1).

Through access based consumption, consumers acquire consumption time with products. Such consumer demand may be met through the provision of use orientated PSS, in which the ownership rights related to the product are retained by the service provider and the customer purchases use of the product over a specified period of time. Examples include sharing/ pooling, renting and leasing. Thus CCT research challenges the reasons stated in the PSS field for why PSS are not widely implemented in consumer markets and indeed, suggests that PSS offerings may have a reasonably promising future in certain aspects of these.

Case study: pilot baby care PSS

Case study research focusing on the provision of pilot baby care use orientated PSS was completed. The pilot study was funded by the UK Government, while the case study research on it reported here was undertaken as part of one of the authors' doctoral studies. The pilot PSS included the provision of baby car seats. Here, participants could rent (i.e. access) a baby car seat from a participating manufacturer. The PSS offerings were promoted through the National Child Birth Trust (NCT) and a project website. Over 400 people have participated in the pilot project, all of whom had recently given birth or were pregnant. In depth semi structured interviews have been conducted with 23 participants, which expressed a preference to be interviewed via the project's website. Qualitative data generated were analysed using a flexible template approach (Robson, 2011). Preliminary analysis showed that four consumers exhibited nomadic characteristics. These form the focus of the results detailed below.

Results

According to Bardhi et al. (2012), global nomadism involves (1) serial relocation, (2) frequent international mobility, and (3) deterritorialization. The lifestyles of the four selected participants exhibit these characteristics. Susan and John are professional actors from Canada and England respectively and have American ancestry. They move extensively for work:

"*Well we go where we work…we spend time in America, Canada, here… we are travelling artists*."

Amy is a Canadian married to an English husband. She relocated to the UK near Oxford for a research contract for a few years, and now she is returning to Canada in six months:

"*We're only going to be here for six more months.*"

Charlotte is a mechanical engineer working at a British aircraft engine manufacturer and has gone through both international relocations, moving between North America, Texas, Sweden and India:

"*I don't think I've lived anywhere more than three and a half years since I graduated from University.*"

Chiara is an Italian researcher married to an Italian academic and has lived in the UK for a few years. The nature of her work could offer an opportunity for a stable location. However, her husband is looking into alternative employment, which is likely to precipitate another move to a different country.

Thus all participants had undergone serial relocations and frequent international mobility. Interestingly, in contrast to migrant consumers studied in previous research (cf. Belk, 1992) global nomads do not anchor their identity in a given territory. Rather they exhibit deterritorialization, which is reinforced by global mobility. Consistent with the findings of Bardhi et al. (2012), for participants, country of origin did not seem to provide a reference point that shaped participants decisions. Indeed, home seemed to be something they could choose rather than a birth place or permanent residence. However, while participants may not have strong bonds with a particular territory, they are part of cosmopolitan mobile and professional lifestyles which reinforce and shape their preferences. Thus enduring strong attachments to possessions and the tangible are devalued in global nomadism. The uncertainty and unpredictability that characterizes nomadic lifestyles means that the participants resist solid relationships to the material world and do not find identity through linking value in possessions. For participants, events such as frequent relocation liquefy their views of possessions. Here, they seemed to value detachment and flexibility, and exhibit a somewhat practical logic toward possessions *(Ibid.)*. This is characterised by (1) situational value, (2) instrumental use value, and (3) immateriality. We consider each of these aspects of a liquid relationship to possessions in light of participant responses below.

Situational value

Nomadic consumers exhibit a flexible relationship to possessions, valuing them in each locale rather than forming an enduring attachment over time and space (Bardhi et al., 2012). To some degree, such consumers reterritorialize themselves as they travel. As part of this process, they use products to establish the ability and authority to act in new contexts *(Ibid.)*. Thus for nomadic consumers, the situational value of products is highly prized.

Amy, who is going to move in six months, highlights the situational value of the pilot PSS offering.

A "car seat is £150 to buy new but I knew I'd only be using it for six months….So that's ideal for me because I don't have to invest a lot in something I'm just going to get rid of."

In the UK a car seat is a legal requirement and a baby cannot leave hospital by car without one[1]. Interestingly, if Amy was not planning to move from the UK, she states that she would have purchased a car seat

"*I would have bought it if I was going to be here indefinitely, I would have bought the (*Maxi-Cosi*) Pebble*" (a model of car seat).

So the liquid relationship she has with the car seat appears to be linked to her temporary UK residence and highlights her need for situational value.

Instrumental use value

A second aspect of liquid relationships to possessions is an emphasis on instrumental use value. Here, use value is defined as the instrumental functionality an object possesses and contrasts the symbolic value that has been emphasized in much consumer research (Bardhi et al., 2012). Instrumental value predominates in global nomadism as it translates cross culturally better than symbolic or identity value *(Ibid.)*. And objects valued for their functionality are also easier to disconnect from without personal loss, and as such they are more liquid *(Ibid.)*.

PSS design strategies typically involve examining the functionality of products and meeting such needs for functionality through PSS (Roy, 2000). Thus use value is a major aim of PSS provision. Among the four participants, the use value of the pilot PSS was of interest. For example, Susan and John stated that they needed the pilot PSS to meet their needs for functionality: they would use the car seat for the leasing period to transport their baby in a car (in a safe way) that meets legal requirements.

"*we needed it for that amount of time… and it seemed, it was a cost-effective way of having the thing for the amount of time that we needed it."*

Immateriality

The physical weight (lightness) of possessions appears to be of importance to nomadic consumers. Possessions valued by this group are flexible, light or in virtual form (Bardhi et al., 2012). Participants valued the intangibility and functionality of the pilot PSS offering. Here they preferred temporary and flexible relationships to products rather than strong enduring ones. For example, Amy stated that

"*we have all these kids' toys and everything but, we're going to throw them out in six months… So that's ideal for me because I don't have to invest a lot in something* (a baby car seat) *I'm just going to get rid of."*

Furthermore, Charlotte seems to be decisively against buying many baby products:

"I didn't want to have a lot of clutter, you hear a lot of people who have children and they end up at the end with all the stuff they need to get rid of and we specifically wanted to try to not have that much clutter, just get the minimum of what we needed, because it's so easy to go overboard.",

Thus both Amy and Charlotte appear to want to "travel light", which suggests a preference for immateriality exemplified by a positive engagement with the pilot PSS.

Conclusions

In this paper we explored the proposition that nomadic consumers exhibit a liquid relationship to possessions that in turn, gives rise to demands for access based consumption (Bardhi et al., 2012) which may be met through use orientated PSS provision. The case study

[1] gov.uk/child-car-seats-the-rules

research presented here is by no means definitive but suggests that this may indeed, be worthy of further investigation. Suggested lines of inquiry, include:

1) Insights from CCT could provide useful insights in the PSS field, especially highlighting the nature of consumption dynamics beyond acquisition. Indeed, a dialogue between researchers working in these fields could be usefully promoted. The future here may lie in combining insights from PSS literature on supply side perspectives with those on access based consumption from CCT. Indeed, an integrated, perhaps less positivistic *socio-technical* perspective could be developed (cf. Cook, 2014*)*.
2) Global nomads who exhibit a liquid relationship to possessions should be further researched to better understand the value of PSS offerings to them and how these can be met.

3) Whether global nomadic lifestyles and liquid relationships to possessions are inextricably linked may also be questioned. Such liquid relations may not be confined to nomadic consumers and thus opportunities to promote PSS may not be limited to this group.

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Hadal or epipelagic? The depths, and shallows, of material experience

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Keywords: emotional durability; depth; meaning; materials experience.

Abstract: As design researchers, searching for clues within the complex product life space, we are drawn toward objects that matter – the photos of our children, letters from loved ones, the inherited watch from a long-passed grandparent or those shoes you wore at your wedding. Commonly, in product life research, we examine closely these emotionally durable objects, in the hope of discovering some secret to their success, which we might then render transferable across to their anonymous mass-produced neighbours. How much can really be gleaned from these idiosyncratic items, and to what extent are we establishing unrealistic expectations by placing them centre stage?

Using the metaphor of the ocean, this paper reframes products in terms of depths and shallows of our material experiences. Taking us from the handful of objects occupying the seldom seen, *hadal zone* of our deeper material world, to the abundance of material goods occupying the surface, or *epipelagic zone*. Through reframing material experience in this way, the paper aims to expose and discuss previously obscured features of the product life space to inform future direction. Indeed, product life research is currently hampered by a preoccupation with hadal items, at the very depths of human experience. Through this depth-bias, we overlook the weaker signals emitted by the myriad objects in the shallows. These objects characterize our experience of the everyday, and fill the rooms, cupboards and pockets of our daily lives. Arguably, these are also the objects that generate ecological and social pressure.

Flooding the earth with ‘stuff’

According to the director of London’s Design Museum, Deyan Sudjic, we live in a world drowning in objects (Sudjic, 2008); households with a TV set in each room; kitchen cupboards stuffed with waffle makers, bread ovens, blenders and cappuccino whisks, and drawers swollen with a plethora of pocket sized devices powered by batteries, which themselves are products that take several thousand times more energy to make, than they will ever produce. Never before have we wanted, consumed and wasted so much. In a world smothered in people and products, it must be questioned what – beyond a conventional understanding of functionality – is all this ‘meaningful stuff’ really for, and why does it transform into ‘meaningless rubbish’ so quickly?

So, what does design and meaning have to do with sustainability? Indeed, it may appear that generating meaningful synthesis between such apparently disconnected ideas is like trying to nail ice cubes together. Yet, peel back the slick, polished skin of the made world, and a dark, incoherent and altogether disturbing reality is revealed – one of misplaced agendas, obscure behavioural anomalies and harsh contradictions – showing how at the root of it all, it is the underlying human condition that shapes our impending ecological crisis.

As we inefficiently fumble our way through countless unsatisfactory embraces with material experiences – from skyscrapers to saltshakers – we temporarily connect with a longer-standing struggle to understand complex existential phenomena such as time, mortality, identity, value, selfhood and utopia, for example. So, like trout rising for hatching larvae, we roam the depths of ourselves, gazing constantly upward in endless anticipation of the existential nourishment we crave.

Rapidly rising consumption in newly industrialised countries such as China, India and Brazil puts further stress upon the global environment (Cooper, 2004). The vast majority of resources taken out of the ground today become waste within only three months: waste consisting of plastics, metals and other synthetic compounds no longer recognizable to the microbial decomposers that degrade substances back to their basic nutritional building blocks. It therefore becomes essential to generate deeper understandings of the meanings and motivations underpinning our wasteful and inefficient engagements with the products of material culture.

Flotsam and jetsam

Perhaps due to the normalcy of innovation, material culture is adopting an increasingly expendable, sacrificial persona. Today, an edgy sense of instability surrounds the *made world*, nurtured by continual change to render its offspring fleeting, transient and replaceable orphans of circumstance. Just over a century ago, 'disposability' referred to small, low cost products such as the Gillette disposable razor or paper napkins, whereas today it is culturally permissible to throw anything away anything from TV sets and vacuum cleaners to automobiles and an entire fitted bathroom (Chapman, 2013). Like flotsam and jetsam, the waste generated through this inefficient system coat the surface of our material worlds, obscuring an otherwise rich set of encounters with the inanimate.

One does not need to be an ardent environmentalist to see that there is little or no logic to the way we relate to our environment. We clear carbon absorptive forests, to grow methane-producing meat, and smother vast areas of bio diverse wilderness with ecologically inert urban sprawl, riddled with mazes of oil-dependent highways. This epistemological error (Bateson, 1972) tells us how the earth is finite, balanced, synergistic and reactive, and yet we design the world as though it were separable, mechanical and lasting. Indeed, human destruction of the natural world is a crisis of behaviour, and not one simply of energy and material alone, as is often assumed (Chapman, 2015); the decisions we make as an industry, the values we share as a society and the dreams we pursue as individuals collectively drive all that we accomplish, while shaping the ecological impact of our development as a species. This ecological crisis concerns how we think, and the institutions that purport to shape and refine the capacity to think (Orr, 2004, p2).

The notion of a 'throwaway society' is nothing new, and has been in the public lexicon since 1955. In fact, it was as early as 1932 when American economist Bernard London first introduced the term, 'planned obsolescence' (made popular by Vance Packard in his monograph *The Waste Makers* (1963)) as a means to stimulate spending among the very few that had money at that time. This proposed shift toward an increasingly disposable material world was initially proposed as a solution to dark economic crisis experienced during the Great Depression in the US (1929). However, the ecological impacts of this drive toward planned product failure could not have been anticipated or understood in the 1930s.

Today, however, we are all too aware of the catastrophe-making character of these practices, and they simply cannot continue. As Slade forcefully argues in his rousing book, *Made to Break: Technology and Obsolescence in America*, the concept of disposability was in fact a necessary condition for America's rejection of tradition and our acceptance of change and impermanence (Slade, 2007). By choosing to support ever-shorter product lives, he argues that we may well be shortening the future of our way of life as well, with perilous implications for the very near future.

The process of consumption is motivated by complex emotional drivers, and is about far more than just the blind purchasing of new and shinier things (Chapman, 2015); it is a journey towards the ideal or desired self, that through cyclical loops of desire and disappointment, becomes a seemingly endless process of serial destruction. Link sentence leading to the depths and shallows of material experience, and how much of our materialistic activities occupy the shallows.

Materialism at the shallows

In terms of the depths and shallows of material experience, the level at which materialism manifests – arguably the site of human-made ecological destruction – occurs within the turbulent shallows. This *epipelagic zone* is populated by the plethora of mass-produced objects that fill our worlds. This constantly shifting assemblage of trainers, teapots and toasters are deployed to reflect our equally dynamic and unstable identities. As our identities evolve and change, so too must the products we deploy to both mirror and project these ephemeral ideas. Like a shadow that follows you around, this *stuff* defines you, whether you like it or not.

This form of materialistic value orientation (MVO) involves the belief that it is important to continually pursue the culturally sanctioned goals of attaining, financial success, having nice possessions, having the right image, and having a high status (Kasser, 2004). Materialism is defined as ‘the importance a consumer attaches to worldly possessions’ (Belk, 1984, p. 291) or ‘a set of centrally held beliefs about the importance of possessions in one’s life’ (Richins & Dawson, 1992, p. 308). The products of MVO tend to inhabit the shallows of our material worlds, as opposed to the very different mode of engagement occurring at the depths. In this way, it is clear that material possessions gain social meaning not only because they have instrumental use in sustaining and developing our daily lives but also because they function as symbols of identity, personality and self-expression (Dittmar & Pepper, 1994).

At this point it is important to note the obvious discrepancy between the things that matter, and things that we use to communicate status, identity and self to others. Too often in product life research these two factors are conflated, leading to distorted results, and false insights.

Our most cherished possessions may very well play no part whatsoever in the mediation of our identities, whilst the products we commonly deploy as signifiers of status do not necessarily ‘matter’ to us in any significant way. Objects that occupy the depths of material experience often play an entirely different role to those more abundant objects occupying the shallows.

The constant abyss

As we dive down into the depths of our material worlds, the objects we pass become increasingly personal, and idiosyncratic. On-trend fonts make way for handwritten notes; digital screens make way for torn notepaper and logotypes are elbowed aside by images of forgotten friends, lost family and jilted lovers. In the turbulence of material experience, these enduring *hadal* objects serve to anchor us within a core identity, and we cling dearly to it.

We are each connected to several distinct systems of objects, occupying different depths of material experience. These objects may well sit side by side on our shelves, but are divided by fathoms, in an experiential sense. To an observer, the things we own and cherish may appear superfluous, banausic, [and] even venal (Schultz et al, 1989) yet we cling to them because they possess significant levels of personal meaning, that defines us individually, as separate from society.

On describing the depth and power of inanimate objects, Bruce Hood, author of Super Sense (Hood, 2009), undertook an experiment in which he first hands out a black 1930s fountain pen, which he falsely claimed, belonged to Albert Einstein. Everyone in the audience is desperate to hold it, and shows great reverence and awe toward the object, as though part of Einstein’s soul somehow resided within it. Hood then holds aloft a tattered old cardigan, and asks who would be willing to volunteer by wearing it. Many offer to do so, until it is revealed that the cardigan belonged to Cromwell Street’s notorious serial killer, Fred West. Promptly, almost all volunteers lower their hands. Hood claims that this change of heart reveals something odd: audience members sitting next to one of those who keep their hand raised, and are willing to wear the killer’s cardigan, visibly recoil in repulsion of their neighbour’s openness to this (Hood, 2009). The cardigan is no longer the prime source of repulsion, but more interestingly, the person who feels fine wearing it, or even handling it, must be avoided also (Chapman, 2013).

As *matter* that we must negotiate, products can literally shape our daily experience in ways that spark particular thoughts, and designers can therefore influence what these thoughts are. As Julia Lohman describes: when communicating through objects the meaning is created through the materiality of the object. The materials become words; the design becomes the syntax. The piece speaks without the detour of language (Williams, 2012).

At the very depths of material experience, enduring associations between people and things are not wholly designable. As van Hinte proposes in *Eternally Yours* (1997), ‘[f]or personal reasons one can feel emotionally attached even to a turnip or a hubcap.’ (van Hinte, 1997, p. 234) Each user possesses a unique assemblage of memories, which render objects as vigorous symbols of the self, and carriers of great personal significance. Over 40-years earlier, Benedict in, *Patterns of Culture* (1955), asserted that '[n]o man ever looks at the world with pristine eyes. He sees it edited by a definite set of customs and institutions and ways of thinking' (Benedict, 1955, p. 2).

In the majority of cases, durability is characterized simply by specifying resilient materials, fixable technologies and the application of product optimization methodologies that reduce the likelihood of blown circuits, stress fractures and other physical failures. Yet, durability is just as much about desire, memory and superstition, as it is fractured polymers, worn gaskets or blown circuitry. Although we may assign particular meaning to a given object, or material, meaning cannot exist outside the body. It is within us meaning can be found. Objects, materials or spaces cannot hold meaning in and of themselves – only our interpretation of these things will produce meaning. In this way, meaning draws from lived experience – that which has happened to you up until this point – and is typically associated with sets of abstract relations and conditions, which create a lasting impression on us.

Depth-appropriate design

Whether pitched at a deep, or shallow level, the 'made world' is a consequence – an emergent space in which the human species has progressively found ways to modify and enhance the world around us. The urban spaces we roam, buildings we inhabit, products we use and garments we wear, collectively represent our intellectual capacity to imagine a better world that is beyond our current level of experience. This innate capability to imagine a world just beyond our current level of experience, and then formulate (design) plans to realize those imaginings, is an essential determinant of what it is to be human – to 'reach beyond innate human limitations' (Heskett, 2003, p. 16).

During product development, designers and manufacturers have a moral obligation to consider longevity and minimized lifecycle impacts (Van Nes & Cramer, 2005; Cooper, 2005). Consumers need to be aware of life spans and lifecycle impacts when buying products (Cooper & Christer, 2005). However, designing longer-lasting products without a clear understanding of the depth at which you are engaging users, is like packing a suitcase for a trip to an unknown destination, and not knowing what you will be doing when you get there. The picture is incomplete, and forces gross generalisations to be made. As stated earlier, there are clear discrepancies between the products that matter, and the products we deploy as signifiers of identity and social position, for example. In confusing these two aspects of material experience, results risk distortion, and insight becomes misleading.

We are currently experiencing a seismic shift in thinking, from the design and delivery of short-life products, to that of longer-lasting material experiences and services. Longer lasting products have the potential to present robust economic models for creating products, services and brand-loyal customers - driving future sales, upgrade, service and repair. Simply having more stuff stopped making people in Britain happier decades ago. The New Economics Foundation (NEF) argue for an economy of better, not more. One of things that last and can be repaired many times before being recycled, allowing us to share better the surplus of stuff we already have (NEF, 2012).

Until recently, sustainable design methodologies have seldom engaged with the more fundamental questions such as the meaning and place of products in our lives, and the contribution of materials goods to what might be broadly termed, the human endeavour (Walker, 2006).

We must design at an appropriate depth, to enable a more targeted approach for products that last. It is repellent, to conceive of a material world, in which all possessions are priceless and indispensable. Socially, this transposes us into an obsessive culture, characterized by over attachment to our things, and anxiety formed through heightened material dependency. However, it is clear that there are opportunities for designers to engage users at a greater experiential depth, as a means to form longer-lasting bonds.

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Opportunities and challenges of new product development and testing for longevity in clothing

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Keywords: clothing performance; new product development; product testing; durability; longevity.

Abstract: Many types of clothing are now seen as disposable by consumers in the UK even though durability is among the top criteria that consumers claim to use when buying garments (WRAP, 2012). Routine tests for clothing performance carried out by retailers are generally designed to ensure garments are 'fit for purpose', not to establish durability or longevity. Designing clothing that lasts longer is, however, key to reducing waste and has become a government policy objective (Defra, 2011).

This paper discusses the findings from a recent research project, carried out for WRAP (Waste and Resources Action Programme), that investigated the opportunities for measuring, specifying and communicating aspects of clothing longevity within a Longevity Protocol. The Protocol is intended to enable retailers to obtain a reliable indication of garment life expectancy and was piloted in conjunction with clothing industry practitioners. It incorporates recommendations for best practice in product development and a testing regime that provides an indication of garment life expectancy (WRAP, 2014).

Overall, the findings from the pilot suggest that it is possible to test for garment longevity, however, this process can be drawn-out and may not fit easily into the normal product development process. Furthermore, variations in consumer wearing patterns and laundering make it difficult for retailers to guarantee and communicate product lifetimes in absolute terms.

The research adds to a growing body of evidence that supports the concept of design for clothing longevity. The findings will help to inform strategies for the implementation of government policy on sustainable clothing, but point to the need for refined testing processes to support this agenda.

Introduction

Clothing products have an average lifetime of 3.3 years, although there is considerable variation between different types (WRAP, 2013). While many discarded items are reused, either in the UK or overseas, others are thrown away because they are damaged or worn out (Morley et al., 2009; Cooper et al., 2013). The Sustainable Clothing Action Plan (SCAP) seeks to reduce the environmental impacts of clothing supply, use and disposal by identifying good practice which could be adopted by retailers and their suppliers. An assumption is made that garment longevity ('keeping a garment looking good and in use for longer') need not impact on commercial returns and could contribute to increasing brand value. Furthermore, evidence suggests that over a third of the population would like to do more to buy clothes that are 'made to last' (WRAP, 2012, p.22).

A research team from Nottingham Trent University was commissioned by WRAP to develop an industry-supported approach to measuring, specifying and communicating aspects of clothing longevity to help to increase the active lifetime of clothing in the UK. The primary outcome took the form of a 'Longevity Protocol' for use by retailers who are stakeholders of the SCAP, and by the clothing sector more widely (WRAP, 2014). The Longevity Protocol combines a 'best practice' approach to product development with the appropriate physical performance and quality tests in the context of specific garment types, to provide an indication of life expectancy. The

Protocol is intended to serve as an aid to garment technologists and designers to ensure greater compatibility of performance standards, as failure will depend on the lowest common factor, and should enable retailers to communicate an indication of life expectancy to the consumer with confidence.

In order to be successful, it was necessary to gain sufficient industry consensus with regard to the testing and performance standards and product development processes that could result in longer garment lifetimes. This paper discusses a 'longevity testing' pilot that was carried out to inform the development of the final Protocol and concludes with an assessment of its feasibility in relation to replicating consumer behaviour in wearing and laundering practice..

Research methods

The Longevity Protocol was developed through a research process that included:

- A visual survey of 1,476 discarded garments viewed at textiles recovery centres to identify common causes of garment failure
- Approximately 30 interviews with industry practitioners to inform best practice in product development and testing regimes for clothing longevity, and
- A 'longevity testing' pilot to evaluate how well the lifetime of certain garment types could be assessed.

The research findings informed the development of a draft Longevity Protocol which was presented to key retailers and suppliers for feedback. The longevity testing element of the draft Protocol was then trialled as a working tool for clothing industry practitioners, and the results of this pilot were incorporated into the final version.

The longevity testing pilot

The initial research with clothing retailers and suppliers informed the development of the following elements of the Longevity Protocol:

- A 'best practice' approach to new product development in which garment longevity is considered from the initial design stage and involves input from designers, technologists, buyers and suppliers working together to ensure a cohesive and integrated approach
- a set of recommended physical performance and colour fastness tests based on a range of 'basic' or 'core' clothing products that give an indication of fitness for purpose, and
- a longevity testing regime that uses a combination of extended wearer trials and repeated care label wash cycles to give an indication of garment lifetime.

1.Identification of recommended physical performance and colour fastness tests

The recommended tests are based on existing British, European and International standards as applied to a range of generic core products. The pass/fail criteria for pilling and colour fastness is based on a scale of 1-5 with grade 5 being the highest level of performance and grade 1 the lowest. Dimensional stability standards are based on a percentage tolerance of shrinkage or extension. While the tests are already widely used in industry, the performance criteria has in some cases been set higher in the Protocol than is currently practiced. For instance, the pilling performance pass for knitwear is set at grade 4 for the Protocol, whereas it is often set at grade 3 in industry. Clothing companies are advised to interpret these tests within the context of the product to take account of variation in fibre use and fabric construction. The selected products and their testing criteria are shown in Figure 1.

Feedback from textile testing companies indicated that physical performance and colour fastness tests are designed to give an assessment of a product's fitness for purpose, and only represent the early stage of the garment lifetime. Retailers also reported using wearer trials to supplement the tests to achieve a more accurate representation of garment performance as a consumer would experience it. This normally involves assessing the product's performance during 50 hours of wear and 2-3 washes. However many industry interviewees found it challenging to factor this in to the product development process due to the short development lead times required for certain products.

Core Test	Knitwear	Shirt	Jeans	Socks	T-shirt
Dimensional Stability to washing/dry clean	+or- 5%	+or- 3%	+or- 3%	to fit sock boards or volumetric legs	+or- 5%
Pilling	Pass grade 4	n.a.	n.a.	Pass grade 4	Pass grade 4
Care Label Wash with visual assessment	expert judgement	expert judgement	expert judgement	expert judgement	expert judgement
Colour Fastness to: - Washing* / dry clean - Water or perspiration* - Light - Rubbing *(*includes shade change and staining)*	Pass grade: 4 4 4 4	Pass grade: 4 4 4 4	Pass grade 4 4 n.a. 4	Pass grade 4 4 n.a. 4	Pass grade 4 4 4 4
Spirality	3%	n.a.	n.a.	n.a.	3%
Seam slippage	n.a.	80N for 6mm opening	n.a.	n.a.	n.a.
Seam strength	n.a.	100N at breakdown	n.a.	n.a.	n.a.
Fusible lamination	n.a.	appearance after wash	n.a.	n.a.	n.a.

Figure 1. Table of recommended physical performance testing criteria for some core product types. Source: WRAP, 2014.

2. Product selection

The pilot was carried out on a range of core basic products identified as being the most appropriate for inclusion within the Longevity Protocol. The visual survey of discarded clothing had identified the key issues as being pilling of knitwear and jersey products, localised abrasion on woven trousers (especially jeans) and general colour fading across woven and knitted products (Cooper et al., 2013). Responses from UK clothing company participants had indicated that longevity is a challenging concept in an industry that is based on introducing new products each season in the context of the 'fast fashion' model that has seen prices reduce and volumes rise in recent years. However, durability (which can contribute to clothing longevity) is already being considered pro-actively by some retailers as part of a quality and value statement to the customer in certain product areas:

- 'Core basic' products in men's and womenswear (for example jeans, formal shirts, basic t-shirts and classic knitwear). Durability testing may be carried out on existing fabrics, and when new fabric bases are introduced, including those that have been engineered for durability and may be marketed as such. The product development process may have a longer cycle as these are not fashion items.
- School wear, which may undergo heavy daily wear and laundering. Improvements to fabric durability, seam strength and component attachment may be considered along with designing features to allow for growth such as expandable waists, and adjustable skirt and leg lengths.
- Risk assessed fashion products, for example where the performance of a new fashion fabric, print or embellishment is of potential concern and may undergo several washes or a durability test to assess its performance.

Due to the wide range of product types within the UK clothing industry, it is envisaged that retailers and brands will identify appropriate products to be considered suitable for the longevity approach. For the pilot, it was decided that a range of core basic adult clothing products would be used (Table 1). The products were donated by a 'value' clothing retailer and a knitwear supplier to a major UK clothing retailer.

Product	Fibre Composition	Colour
Women's crew neck jumper	100% cashmere	Light beige mix
Men's denim jeans	100% cotton	Dark blue
Men's formal shirt	65% polyester, 35% cotton	White
Men's crew neck t-shirt	100% cotton	White
Men's socks	78% cotton, 20% nylon, 2% elastane	Black

Table 1. Table of core products that underwent the longevity testing process.

3. Development of the longevity testing method

The aim of the pilot was to assess whether longevity testing could pinpoint possible areas of 'first fail' not identified by routine physical and colour fastness tests, and therefore be a valuable way of informing future product development where longevity is desirable.

In order to assess garment lifetimes it is appropriate to use a testing regime that is more representative of lifetime wear. There is no formalised test method for clothing longevity, but retailers reported using a range of approaches to assess durability beyond the basic physical and colour fastness tests (which only give an indication of fitness for purpose rather than a representation of the garment lifetime). Methods are used individually or in combination with each other, and include the following:

- Extended wearer trials (of up to 200 hours or longer).
- Formal durability tests to replicate a number of multiple washes.
- Repeated care label wash cycles, where garments may or may not be dried in between each cycle. Products may be visually assessed at intervals.
- Extended abrasion / pilling tests.

The pilot assumed that the selected core products had already passed the basic performance tests in line with normal industry practice. A longevity testing regime was then devised based on extended wearer trials and a number of repeated care label wash cycles. As actual usage environments and behaviour by individual consumers may vary considerably, this would allow companies to specify and communicate lifetimes in terms of 'wear and wash' cycles rather than years. An attempt was firstly made to calculate the lifetime of each garment in terms of the number of hours of wear and number of washes a consumer would experience. In each case, the estimated lifetime was increased by around one third in comparison to data on current garment lifetimes (WRAP, 2013), in line with the SCAP proposals to increase clothing lifetimes (WRAP, 2012). However, it became clear that due to insufficient time within retailers' product development cycles it would be virtually impossible to accurately test garment longevity by replicating lifetime consumer wear through extended wearer trials and repeated wash cycles (Table 2).

Longevity factors	Knit-wear	Shirt	Jeans	Socks	T-shirt
Current lifetime estimate (years)	3.7	3.6	3.1	1.8	3.3
Target lifetime (years)	5	5	4	2.5	4.5
Hours of wear for the target lifetime	**1,800**	**960**	**3,600**	**1,500**	**1,350**
Hours of wear per wash	60	24	120	24	24
Average number of washes for the target lifetime	**30**	**40**	**30**	**62**	**56**

Table 2. Estimates of clothing lifetimes expressed in number of hours wear and number of washes. Source: adapted from WRAP, 2014.

Extended wearer trial procedure

Feedback from industry had confirmed that wearer trials provide valuable insights into effects of the wearing process on garments to complement insights from wash cycle tests.

The extended wearer trials were designed to be conducted for substantially longer than the 50 hour trials commonly used by many retailers and brands, in order to assess if this procedure could contribute to estimating the 'normal' life-expectancy of a garment. The trials undertaken in the pilot were intended to last for 200 hours. Used products were compared against a control garment at the end of the trial.

Wearers were issued with garments and supporting documentation to complete, which included specified care label instructions to follow. Wearers were required to complete information on hours of wear each day, method of washing and drying and frequency of washes, together with descriptions of the condition of the garment before washing, after the first wash and after each 50 hours of wear. Garments were returned to the research team at 50 hour intervals, whenever possible, and visual assessments against a control garment and dimensional checks undertaken.

Repeated wash cycle procedure

The repeated wash cycle tests were undertaken by a leading textile testing company where identical garments of the five product types underwent extended wash testing. The aim was to see if garment failure might occur before the 'lifetime' estimate used for the product category in the draft protocol. Each product was washed according to the care label either 20, 40 or 50 times depending on the product category, fibre composition and care instructions. The total number of cycles was based on researchers' knowledge of the likely frequency of wash and wear of the specified products (Table 3). They were compared with a control garment at intervals during the process and assessed against the relevant testing criteria for that product.

The tests produced objective measurable data on the key aspects of physical performance (such as pilling, abrasion and dimensional stability) and colour fastness, enabling comparison with the wearer trial results. After the wash tests the garments were inspected by both test house and NTU staff.

Test / Trial	Knit-wear	Shirt	Jeans	Socks	T-Shirt
Number of repeated wash/dry cycles	20 (cash-mere)	40	40	50	50
Target wearer trial hours	200	200	200	200	200

Table 3. Number of repeated wash cycles and target wearer trial hours by product. Source: adapted from WRAP, 2014.

Findings of the longevity testing pilot

Extended wearer trials

A total of 12 garments across the 5 product types completed around 200 hours of wear each (2 knitwear, 2 shirts, 2 jeans, 3 socks and 3 t-shirts). The extended wearer trials proved complex and time consuming, reinforcing a concern that they may be considered unrealistic by some companies due to the time taken to complete (except for classic styles where there may be a longer lead time to market).

A higher number of trials had been attempted but some wearers abandoned the trial early due to a range of problems resulting in non-completion. These included seasonal weather and wearers becoming bored with a garment because they needed to wear it more often than normal. There also proved to be difficulty in finding reliable wearers who were able to provide constructive feedback.

Failure to complete the trial period reflected the significant commitment involved. A further concern was that it is uncertain whether triallists behaved as they would with their other clothes; for example, the cashmere jumper may have been washed more carefully if the wearer had paid for it themselves.

Wearer trial evaluation

The trials demonstrated that garments subject to an average 200 hours of wear show some signs of deterioration, although this was mostly insubstantial except in the case of cashmere knitwear and socks. The cashmere knitwear suffered from pilling and dimensional stability problems and although the garments remained within the retailer's tolerances for shrinkage, one sample (which had been washed at too high a temperature) was outside the tighter tolerances advised by the Protocol. The socks were affected by significant pilling and colour fading to a level that did not meet the test pass/fail criteria. The level of colour loss in two of the sock samples was thought to have been caused by using an inappropriate detergent that contained optical brighteners.

Repeated wash cycle tests

The wash tests proved very useful for showing the point at which garments failed against aspects of the Protocol performance criteria. The testing took around four weeks to complete for the products able to be tumble dried; the cashmere knitwear took longer due to having to be dried flat after each wash.

Particular areas of first failure were socks and jeans colour fading, cashmere shrinkage and pilling, t-shirt dimensional stability and sock pilling (Table 4).

Repeated wash cycle evaluation

An advantage of wash tests revealed by the study was that they appear more realistic than extended wearer trials given short product lead times. The number of tests ranged from 20 to 50, depending on the type of product, significantly more than the norm, which is often five care label washes carried out as a durability test by some retailers. The increased number was beneficial as certain problems were not evident until later washes. In the case of knitwear, for example, significant pilling was only evident by the 10^{th} wash and in the case of jeans significant colour loss was only apparent after the 20^{th} wash. With socks, pilling was evident after the 5^{th} wash, but the rate of deterioration was only apparent after the 20^{th} wash and colour loss was only significant after the 30^{th} wash.

Product	Pilling Test	Dimensional stability Test	Colour change/loss assessmernt
	Pass/fail criteria: **grade 4 or better**	**Pass/fail criteria:** **knitwear and t-shirt+/- 5%** **shirt and jeans +/- 3%**	**Pass/fail criteria:** **grade 4 or better**
Knitwear 20 wash cycles (cashmere)	Grade 3 by 5th wash, grade 1-2 by 10th wash	Width shrinkage is out of tolerance by 10th wash. Whole garment shrinkage is out of tolerance by 15th wash. Shrinkage is progressive	No issues
Shirt 40 wash cycles	n/a	No issues	No issues (white shirt)
Jeans 40 wash cycles	**n/a**	Shrinkage is slightly outside tolerance from the 10th wash, but is not progressive	Grade 3 by 20th wash, grade 2 by 30th wash
Socks 50 wash cycles	Grade 3 by 5th wash, grade 2 by 30th wash	Unsatisfactory shrinkage by 40th wash	Grade 3 by 30th wash
T-Shirt 50 wash cycles	Grade 3-4 by 40th wash	Length shrinkage out of tolerance by 5th wash. Garments become progressively shorter and wider.	No issues (white t-shirt)

Table 4. Physical performance of products undergoing repeated wash cycle tests. Source: adapted from WRAP, 2014.

Conclusions

The longevity testing pilot demonstrated that carrying out a series of care label washes representing a lifetime's laundering of a garment is effective in showing a level of durability beyond that revealed through current tests. Even so, in seeking to measure longevity of clothing it is difficult to give a definitive quantified guideline for the recommended number of hours for extended wearer trials and the number of wash test cycles. Longer wearer trials (perhaps 500 hours) would be needed in order to obtain conclusive data: the 200 hour trials did not result in enough washes to allow for comparison with results from the repeated wash tests, and different drying methods were a further complicating factor. The number of wash cycles used in these tests broadly reflected the number anticipated during the lifetime of the selected garments, but the wearer trials indicated that there is considerable variation in the frequency of washes per hours of wear.

The longevity testing element within the final version of the Protocol therefore proposes a basic framework that includes wearer trials of up to 200 hours and a series of repeated wash cycle tests based on a range of generic core products. Users are advised to interpret these in the context of their own products, considering end use and fibre composition.

The potential benefit of the Protocol to companies is that a minimum standard of good practice can be embedded across the product range, reinforcing brand value. It provides a structured approach for development teams to ensure that good practice is achieved for all garments, minimising the potential cost of discovering poor quality at a later stage. It also offers workable regimes for garment testing that build the knowledge and experience necessary to predict, identify and avoid sub-standard performance and premature failure.

Further research would be needed to give more accurate recommendations for testing clothing longevity based on a specified number of wash tests and wearer trial hours. Guidelines would need to be specific in terms of fibre, fabric and garment type and could take the form of a range to allow for different user behaviour (i.e. wear frequency, user environment and laundering). This project did not directly address the context of consumer behaviour but future studies could investigate consumers' understanding of fibres, fabrics and care labels as well as patterns of wearing and washing of clothing. This could inform the development of more accurate longevity testing regimes and influence the communication of care instructions. In addition, the need for a more standardised approach to testing for longevity was highlighted by retailers; currently there is no formal test method that represents more than five care label washes.

Future research could consider opportunities to develop a new test that combines the lifetime wearing and washing impact on clothing in order to give an accurate estimate of garment lifetime. Developing an accelerated method that is more representative of the range of consumer behaviour could also be effective in reducing the time taken to carry out longevity testing compared to the extended wearer trials and repeated wash cycle tests used in the development of the Longevity Protocol.

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Implementing a circular business model in an SME manufacturer of a plastic packaging product

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Keywords: Resource efficiency; circular economy; closed loop recycling; LCA; product re-use.

Abstract: In 2013/14 Resource Futures led a Technology Strategy Board (TSB) funded study to determine the feasibility of implementing a circular economic business model for Phineas Products Limited. The circular economy, as applied to Phineas Products, involves a system in which products are manufactured in the UK and recycled only when the product has reached the end of its usable lifetime.

The objectives of this feasibility study were:

- To understand the baseline business model for Phineas Products' main product line, the stackable shoe hanger, and to develop four system alternatives
- To determine the technical feasibility of the alternative models on a range of material formulations for new products to assess the quality/durability
- To undertake economic and environmental analyses, including sensitivity analysis and identification of critical variables
- To quantify the potential economic and environmental benefits of full-scale implementation of each of the options.

The study found that re-use systems would be associated with significantly less CO_2 per hanger than the baseline and recycling models examined. The largest potential savings in the re-use models came from the reduced manufacturing burden and material production emissions. Smaller gains were also realised in the distribution and the disposal emissions. The study also found that the re-use models offer the greatest financial costs savings over the baseline disposal hanger as might be expected by the reduced material requirement and distribution impact. Following the study, Phineas Products has re-shored approximately 50% of its manufacturing operation and established a closed loop recycling system for its products.

Introduction

Introduction

This paper presents the results of the Technology Strategy Board (TSB) funded 'New designs for a circular economy' study to determine the feasibility of implementing a circular economic business model for Phineas Products Limited. Undertaken as a collaboration between Phineas Products Limited, Resource Futures, and the University of Warwick, the aim of the project was to evaluate the economic and environmental impacts, as well as the technical feasibility of transitioning to a more circular business model for a specific product line of Phineas Products' portfolio. The circular economy, as applied to Phineas Products, involves a system in which products are manufactured in the UK from UK-sourced recycled material, designed to be used and re-used in closed loop cycles, and recycled only when the product has reached the end of its usable lifetime.

Phineas Products Ltd

Phineas Products Ltd., based in Bristol, UK, designs, manufactures and distributes a range of bespoke plastic shoe hangers and boot clips for some of the largest multinational clothing and shoe retailers. The company has been in operation for 27 years, during which it has built on-going and successful relationships with retailers such as Clarks, Marks & Spencer, Mothercare and Next. Phineas manufactures over fifty million hangers per annum, most of which are used in the UK each year, representing the majority of the domestic shoe hanger market. The company has strong environmental, ethical and social policies, and is committed to advancing the sustainability of its operations by redesigning its product portfolio, trailing new materials, improving production efficiencies and developing new business models to further reduce the environmental impact of its products.

The present model

Phineas' business model at the time of study was linear in nature and serves as the *baseline model* against which all costs whether financial or environmental are compared. The baseline model (Figure 1) was broadly as follows:

Hangers manufactured in China (using virgin material)

↓

Transported to shoe factory (Asia or Europe)

↓

Shipped to UK with footwear

↓

Hanger and footwear distributed to stores

↓

Hanger either: a) given to customer, b) disposed of with mixed waste by retailer, or) sent for recycling

Figure 1. Schematic indicating the baseline manufacturing system

Although this model has been very successful historically, Phineas wanted to investigate transitioning to a more resource efficient, circular economic business model for a number of economic and environmental reasons. In terms of economics, the availability of quality in Asia can be variable and both raw materials and labour costs are forecast to rise in price, impacting upon profit margins and threatening the economic viability of the current model. On the environmental side, public and governmental pressure (in particular, the Sustainable Clothing Action Plan (SCAP) and the Packaging Essential Requirements Regulations) is encouraging retailers to examine the environmental and social credentials of their supply chains. Clients of Phineas were beginning to ask for re-usable products to reduce the materials dependency of their operations and meet the Corporate Social Responsibility objectives. Given these drivers, Phineas is considering new ways of supplying retailers with products and seeking competitive advantage in doing so.

The objectives of this feasibility study were:

1. To understand the baseline business model for Phineas Products' main product line, the stackable shoe hanger, and to develop four circular economy business model/system alternatives, each with a different manufacture/distribution/disposal/re-use configuration.
2. To determine the technical feasibility of the proposed business models by conducting Dynamic Mechanical Thermal Analysis on a range of material formulations for new products to assess the quality/durability, and the effect of the addition of commercial additive packages.
3. To undertake economic and environmental analyses on the baseline and each of the four system options, including Life Cycle Carbon Assessment (CO_2eq), Life Cycle Costing and Sensitivity Analysis.
4. To quantify the potential economic and environmental benefits of full-scale implementation of each of the options.

Methodology

Mechanical Thermal Analysis was undertaken to assess the quality/durability. The effect of the addition of commercial additive packages was also assessed. These analyses were undertaken by the University of Warwick.

A spreadsheet based model was developed by Resource Futures for the modelling performed in the project. System data was provided by Phineas Product Ltd for the baseline model. A number of business model options were also framed and investigated for the project. In total, the following options were examined:

1. Baseline - the majority of the Phineas Products hangers are produced in China from virgin polystyrene and polypropylene, and then distributed to approximately thirty customers across India, China and Vietnam. Most hangers are then packaged with the shoes and distributed to the UK by sea freight. Upon arrival in the UK, the hangers are transported by road to a number of retail distribution centres where they are held before being moved into the retail environment
2. Recycling - The model uses as a default 30% recycled material from secondary sources. Higher proportions are analysed in the study sensitivity analysis as it is possible to create polystyrene products with 100% recycled content
3. Re-use Model 1 - Re-used in baseline supply chain (captured and returned to Asia manufacturing base)
4. Re-use Model 2 - Re-used in UK in supply chain (captured and returned to UK manufacturing base)
5. Re-use Model 3 - Re-used in-store (captured in-store – re-used 5 times in shop).

Data were collected or estimated for each alternative to the baseline. The model was used to undertake both life cycle carbon and life cycle costs assessments for the baseline system and five alternative options across the life full cycle. Sensitivity analysis was performed on key variables in the model including numbers of time each product was re-used and handling time.

Results

Environmental performance

The study found that re-use systems were associated with significantly less CO_2eq per hanger than the Baseline and Recycling options. The greatest savings in the re-use systems comes from the reduced manufacturing burden and material production emissions (See Figure 2). Smaller gains are also realised in the distribution and the disposal emissions.

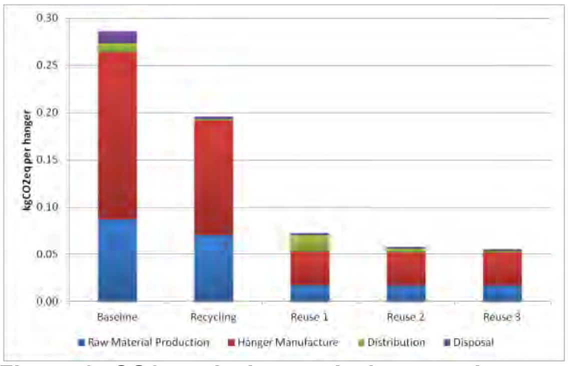

Figure 2. CO2 equivalent emissions per hanger for each of the models and life cycle stages

Financial performance

The study found that the re-use models offer the greatest savings over the baseline per hanger as might be expected by the reduced material requirement and distribution (Figure 3). Of all the re-use models, the configuration where hangers are manufactured in the UK and sent back to Phineas for quality checking and redistribution provided the best financial performance as a result of the lower distribution costs. The re-use model where hangers are re-used in store is modelled to be the most expensive of the re-use models due to the higher cost in the use phase on account of estimated additional retailer handling time. The recycling model shows marginally decreased raw material costs but higher manufacturing costs making it more costly than the baseline and the re-use models. However, as a result of expected oil price rises in the coming decades, the recycling model becomes less expensive than the baseline after approximately five years.

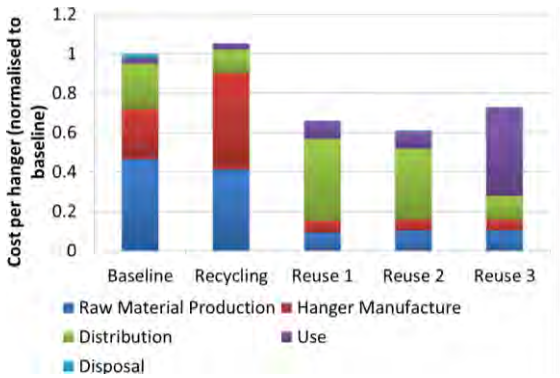

Figure 3. Life cycle costing results of each model (normalised to baseline)

Technical performance

Polystyrene was found to be the best candidate for re-use as a result of its durability and rigidity, followed by polypropylene and talc filled polypropylene. The suitability for assessing potential re-use can be judged by much clearer pass/fail criteria with polystyrene (Figure 4), whereas quality issues such as part distortion were found to affect polypropylene samples to a greater degree. However in all cases an inspection stage is recommended to look for visual signs of stress damage at stressing points mainly located on the joints of the components.

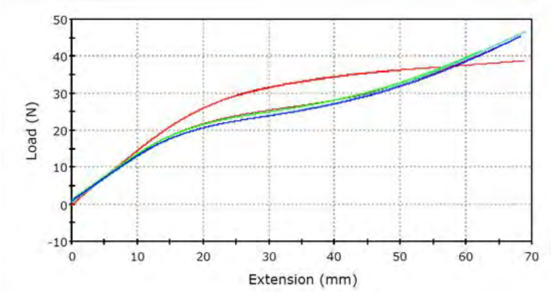

Figure 4. Mechanical testing for five re-use cycles (polystyrene)

A series of sensitivity analyses were carried in the feasibility study to determine the effect of a range of critical variables on the environmental and economic costs of the various models (Figure 5). The following variables were deemed to be critically important in determining the viability of the re-use/recycling models: proportion of recyclate, number of re-use cycles, in-store handling time and oil price inflation.

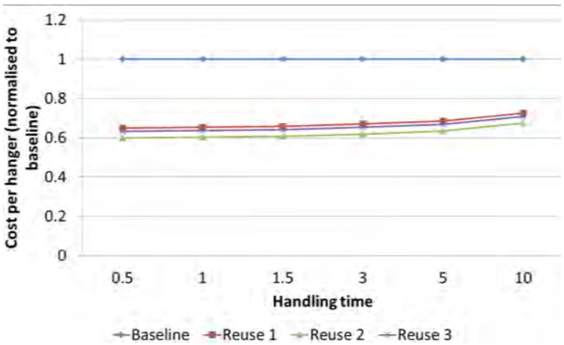

Figure 5 - Cost per hanger with additional handling time in-store

Conclusions

The study intended to answer the question of whether it is feasible from a technical, environmental and financial perspective, to commence large-scale manufacturing of the Phineas Products shoe hanger in the UK and promote the use of the hangers in repeated cycles. The modelling suggested that systems where the products are manufactured in the UK and subjected to multiple re-use cycles do indeed perform better from a financial and environmental perspective. The research also found that the hangers, subject to reasonable use as well as the material used, are potentially durable to endure up to 5 cycles of re-use.

Following the study, Phineas Products has re-shored approximately 50% of its global manufacturing operations to the UK. A closed loop recycling system has also been established for products that are taken back by the retailer. The company has purchased recycling granulation and injection moulding equipment, which they also collaboratively share with an adjacent plastics products manufacturer. Phineas and Resource Futures are seeking further research funding to formally trial a re-use system for their products with a high street retailer.

Acknowledgments

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From rag trade to retail: garment failure and the potential for sustainable fashion

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Keywords: clothing longevity; durability; quality; consumer behaviour; sustainability.

Abstract: Around 1.8 million tonnes of clothing waste is generated annually in the UK, accounting for around 5% of total UK household waste, with the lifetime of many garments unduly short. As a result of greater attention being placed on waste reduction at European Union and national government level, however, interest in the potential for increased garment lifetimes has grown in recent years and, despite obvious tensions between fashion and longevity, retailers have begun to engage in the debate.

This paper presents findings from a research project undertaken for WRAP (Waste and Resources Action Programme) aimed at an industry-supported approach to measuring, specifying and communicating aspects of clothing longevity. Although a high proportion of garments are thrown away in wearable condition, many of which are reused, others are discarded because they are damaged or worn out. This study was concerned with the latter. Although a literature review identified recent studies addressing the context surrounding the fashion industry and elements of the 'fast fashion' debate, providing some explanation for the disposable nature of much fashion, no primary research relating to garment failure was found. A visual survey of discarded clothing was thus undertaken in order to increase knowledge and understanding of reasons for garment failure. Visits were made to three UK-based textile reuse and recycling organisations. Around 1,500 discarded garments in a failed condition were subject to a systematic analysis, categorised by type of garment and condition and with visual images recorded. Only garments no longer 'fit for purpose', deemed not to be in a good enough condition to be re-sold in the UK, were assessed. The method of first hand observation enabled consideration of why items had been discarded and had the benefit of being less subjective and not dependent upon the memory of people who had disposed of them.

The main reasons why garments appeared to have been discarded were identified as colour fading and problems relating to fabric quality such as pilling of knitted items and fabric breakdown in the form of fraying and thinning. Other key issues were general wear around the crotch of trousers and jeans, discolouration in white shirts and holes in seams. The detailed findings, presented by type of garment and type of fabric, will be useful to fashion retailers and brands wishing to respond to growing concerns about waste arising from short-lived clothing. It should enable them to review their performance criteria and testing procedures in order to adjust garment specifications, and to market garments appropriately.

Introduction

This paper presents findings from a research project commissioned by WRAP (Waste and Resources Action Programme), to develop an industry-supported approach to measuring, specifying and communicating aspects of clothing longevity. The project was designed in the context of WRAP's Sustainable Clothing Action Plan (SCAP), which brings together industry, government and third sector organisations to develop targets, tools and guidance in order to reduce the environmental impact of clothing.

The volume of waste generated annually from garments, 1.8 million tonnes, accounts for around 5% of total UK household waste (WRAP, 2012).) The potential to reduce the environmental impact of garments through increased longevity has been identified in research by WRAP (2012) which concluded that extending average lifetimes by just three months would lead to a 5-10% reduction in the carbon, water and waste footprints of clothing. Subsequent research by WRAP (2013) revealed the average lifetime of garments to be 3.3 years although this varies considerably by type: casual clothing has the shortest average lifetime and formal clothes for 'an occasion outside of work' the longest.

There is evidence that a significant proportion of consumers might be interested in longer lasting clothing. In a survey undertaken by Nottingham Trent University and Ipsos MORI for WRAP (2012), 38% of consumers indicated that they 'could do more to buy items that are made to last and would like to do so.'

Product lifetimes have to be defined carefully: around one-fifth of garments have not been worn for at least a year, which prolongs their nominal lifetime but does not imply any reduction in waste. An important distinction is between durability and longevity. Durability is "a measure of how long a product will continue functioning as intended and withstand 'wear and tear' ... before it develops a defect." (Cooper, 2010, p.8). By contrast, a product's longevity describes its life-span (or lifetime) and is "a somewhat different measure, being partly determined by factors other than attributes formed through design and manufacture" (ibid): these include user behaviour towards the item and wider, socio-cultural influences. This distinction is especially important in the clothing sector as nearly one half of all discarded garments are reused (WRAP, 2012), being in wearable condition. By contrast, the focus of this paper is on garment failure and thus on durability.

Key threats to garment lifetimes are fabric failure, component failure, construction failure, accidental damage and colour change. For garments, as with many types of product, the threat of failure can be reduced by setting and testing key quality levels and by design engineering that anticipates risks. Yet within the clothing sector there is currently no common approach to assessing or guaranteeing the durability of garments; nor are there legislative standards that apply directly to durability, other than the general requirement that goods sold are 'fit for purpose'.

Established testing procedures exist for textiles, components and the constructed garment, but they are not used consistently by all retailers. Moreover, the pass/fail criteria are set by each retailer, in some cases varying by product category, and are often linked to the brand or retailers' market position. Even if garments fail the testing criteria and are considered sub-standard, it is common practice for a commercial decision to be made by the retailer to accept the product with a disclaimer attached to a swing ticket; clothing is a sales-driven industry, with fashion often taking priority over quality. Furthermore, many such tests are not directly related to longevity.

Aims

The research was undertaken within the context of a project aimed at developing a 'Clothing Longevity Protocol' for industry stakeholders as a mean of enabling them to reduce their carbon emissions. This paper reports on the project's first phase, in which the specific aim was to understand and explain consumer perceptions of garment failure using secondary research and primary data from a survey on the condition of discarded garments.

Secondary research

There has been wealth of writing on sustainable and ethical fashion in recent years (e.g. Black, 2008, Giesen, 2008, Fletcher, 2008, 2012, Siegle, 2011). In order to explain the disposable nature of much fashion, it is important to consider the context surrounding the fashion industry and, specifically, elements of the 'fast fashion' debate. Understanding consumers' behaviour is also necessary in order to explain the differing points at which people deem their clothes ready for disposal. Finally, the review addresses expectations of garment longevity and evidence surrounding improved durability of textiles. There is very little published research directly relating to garment failure. Some data on clothing longevity and consumer expectations is available from a study for Defra by Fisher et al. (2008); however, this focused on consumer understanding of sustainable clothing and associated behaviour rather than on garment failure.

Over the last 15 years fashion has become faster and cheaper (Black, 2008). The concern is that 'fast fashion leads to fast landfill' (Allwood, 2006: p 65). Yet consumers under the age of 24 have never really known a high street without 'fast fashion': the tradition of two to three fashion seasons per year, with retail collections updated every few weeks, has long departed. Pressures on quick turnaround and price have inevitably led to lower quality. In a survey for Defra, 63% of consumers thought that clothing had become lighter in weight over the previous three years and a similar proportion said that the lifetime of clothing had become shorter (Morley, 2006).

Although there are a few stories of high profile brands and designers refusing to feed this fashion machine, the most notable example being Vivienne Westwood (Bilby, 2012), most retailers are in the business of spotting fashion trends, reacting quickly and providing cheaply. Evidently the many consumers who buy into fast fashion regard such garments as readily disposable.

Nonetheless certain retailers are tackling concern about waste, mindful of growing environmental awareness. H&M and Marks and Spencer, for example, are offering a service whereby they ‘take back’ used clothing and in return provide a discount on future purchases. The overall effect of such an approach is uncertain, however: it may even encourage consumer spending rather than stop it or make it more considered.

Market analyst Francesca Muton (2012) has argued that some fashion trends are starting to extend beyond a few seasons, a reaction to some consumers not wanting to re-invent their wardrobe every season. A groundswell of discussion, along with raw material price hikes (notably cotton), seems to suggest that the time may be right for a re-think of consumption and disposal. On the other hand, recent literature suggests that consumers may take an interest in product lifetimes but that longevity is not a ‘top of mind’ priority and is bound up with other purchase factors (Cooper, 2010; Brook Lyndhurst, 2011. In the case of clothing, the aforementioned survey by WRAP (2012) found that good quality and durability were among key criteria used by consumers when buying clothing. Yet some consumers do not know how to assess quality in garments and judge how long they will last. Thus barely a third checked the type of fabric a garment was made out of by ‘looking at and feeling’ it before making a purchase.

Selling longevity as a proposition has not been well researched (Cooper 2010). Sender (2011) found that the importance of clothing longevity to women increased with their age, reflecting the popularity of fast, disposable fashion among youths and a greater emphasis on durability and quality among older women. Wilber (2013) and Muton (2012) concluded that 16–24 year olds need a story to guide them through quality, unaware of how a good quality button, for example, makes a difference to price, and that such information needs better communicating through marketing and at point of purchase.

A framework to classify which products are more likely to be bought with longevity in mind has been proposed by Brook Lyndhurst (2011). Within this framework is the ‘classic’ product that is less subject to the changing whims of fashion, for which functionality is the key: such products tend to be disposed of when they fail physically in some way rather than due to a change in the fashion trend. Brook Lyndhurst’s research suggested that people do not expect a shirt, jumper, jeans and a coat to last more than 2 years, and proposed “working with retailers and manufacturers to develop ‘anchor’ or ‘classic’ products of home furnishing and clothing that could be marketed as durable lynchpins” (Brook Lyndhurst, 2011, p.52).

Design for durability involves ensuring the physical and technical robustness of the garment (Annis, 2012), as well as addressing the emotional qualities that garments can provide. It requires consideration of the role of the design and production teams, the materials they initially select, the amount and type of testing, and the communication to the consumer.

With pressure constantly to produce new collections, the designer can feel estranged from the user and not feel sufficient incentive to build increased longevity or emotional qualities into the garment. Cooper et al. (2013) have produced a series of guidance notes for increasing longevity in each of eight categories of clothing, aimed at design teams.

In the case of material selection the environmental implications may be complex as the choice has consequences for how products are to be washed and, therefore, the potential for saving energy (Fletcher and Goggin, 2001).

Retailers are already addressing longevity in some product areas, notably school-wear, in which smart technologies such as stain defence finishes are used, and outdoor and technical products, into which durability is being purposefully designed. A related area in which durability has been considered is sportswear. For example, Nike state that to make sure the fabrics do not pill, lose their shape, tear, bleed or fall apart after washing, a testing company puts them through various tests involving abrasion machines and laundrometers (Shellenbarger, 2011). Best practice for clothing in general includes wearer trials as part of the product development process, supplementing wash cycle tests. However, it is problematic to simulate product wear to the degree required within the time constraints of the seasonal critical path.

This review has found that fashion appears to have become faster and cheaper over the past twenty years but that it is an appropriate time for retailers and brands to start reconsidering the durability of certain garments and communicating this aspect of quality to consumers more effectively.

The sustainability benefit from reducing waste by increasing product longevity is potentially substantial. Although consumers expect a relationship between price and durability, the latter appears difficult for them to identify during purchase, and certain types of product, notably ‘basics’ and ‘classics’, appear especially suited to the proposed Longevity Protocol.

As no significant research on physical faults with garments at the point of disposal was uncovered during the review of secondary literature, the need for primary research was confirmed. This was consequently carried out and the findings are reported below.

Method

A systematic analysis of 1,476 discarded garments, classified by type (Figure 1), was undertaken in order to identify the incidence of physical faults. The garments were limited to those judged to be no longer ‘fit for purpose’, having been donated to charity but considered not in a good enough condition to be re-sold in the UK. The items selected were primarily bound for Africa or Pakistan, where they would be re-sold as clothing items if possible and recycled if not. Three textile recovery centres were visited: Traid in London, Oxfam in Huddersfield and IG Cohen in Manchester. The sorting belt at the Traid warehouse from which clothes were selected and analysed is shown in Figure 2.

First hand observation enabled objective analysis of the complete garment, together with consideration of the primary reason why it might have been discarded. As observational research, it had the benefit of being less subjective and not dependent upon memory (Venjatarmani et al., 2006; Zaltman, 1997; Graves, 2010) or subject to inconsistency in language around degradation. It was important to visualise the garments as the spectrum of problems such as colour fade is broad. Visits to textile recovery centres, as distinct from homes, allowed for a large number of items to be analysed over a relatively short period of time.

A simple random sample of items was selected from conveyor belts, bags and bins. The sample included the full range of discarded items: 30% tops, 18% trousers, 15% jumpers, cardigans and hooded tops, 15% nightwear and underwear, 12% outerwear, 6% dresses, skirts and shorts, and 3% school-wear. The items analysed mirrored the type and proportion generally found in textile recovery centres, and the main brands identified broadly reflected the market share of the leading high street retailers.

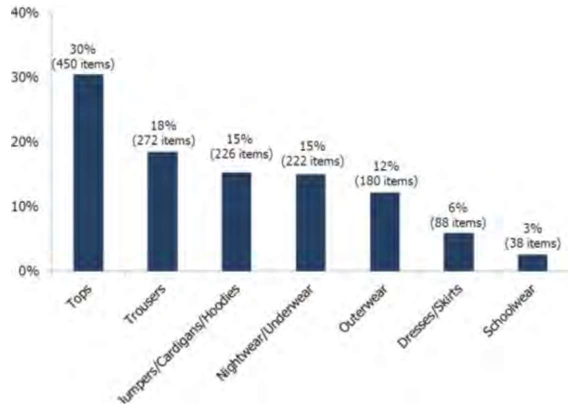

Figure 1. Garments in sample, by type.

Figure 2. Sorting belt at the Traid Warehouse.

Research findings
A visual analysis identified the two main faults in garments as colour fading (particularly for jersey and woven fabrics) and issues relating to fabric quality (most notably pilling in the case of knitwear and jersey). Another common problem was fabric breakdown, particularly for woven garments, in the form of fraying and thinning (especially around hems) and general wear around the crotch of trousers and jeans. Other notable issues included dimensional stability issues with knitted garments, discolouration in white shirts (particularly the collar) and holes in seams (including jacket linings).

Almost 70% of garments analysed had a colour-related problem; this was most commonly fading, but included discolouration and logo issues. Many garments had some kind of fabric-related problem, including a majority with pilling and more than a quarter with fabric breakdown (i.e. frayed, thinned or worn). A fifth had a dimensional stability issue (i.e. stretched or out of shape), and nearly one in ten had problems related to trims such as zips and buttons. In addition, 29% of garments appeared to have been subject to accidental damage (mainly stains or tears). Many garments had multiple faults (hence the total exceeds 100%). In the rest of this section, the findings are analysed first by type of problem and then by type of garment.

Analysis by type of problem
Many garments demonstrated some kind of colour fault. The most common was colour fading (53%), but issues with a logo (16%) and discolouration (15%) were also noted (some garments had multiple problems). Among the discoloured items, nearly two thirds (65%) involved white garments and 13% exhibited discolouration around the collar.

Fabric quality was another common problem. Pilling affected a majority of garments (55%). Over a quarter (29%) showed some kind of fabric breakdown: among these garments 39% were frayed, 23% had thinning and 15% worn fabric. Key problem areas included hems (22% of garments with fabric breakdown), collars (13%) and the crotch (10%).

One in five garments (20%) had a problem relating to dimensional stability, primarily knitwear. Garments were most often categorised as stretched (33% of affected items) or out of shape generally (26%) or at the knees (14%).

Around one in seven garments (14%) had holes in seams, either through seam stitching coming undone or breaking, or the fabric wearing around the seam. Areas most commonly affected were the crotch (21%) and armpit (16%).

There were few failures with trims such as zips, buttons and embellishments such as sequins or gems: just 8% of garments were affected. Of these, missing buttons (46%) and broken zips (22%) were the main issues.

Analysis by type of garment
More detailed analysis by garment type was undertaken on specific items of interest, where sample size allowed. Particular attention was given to less trend-led (or ‘classic’) garments, as these were under consideration for the Longevity Protocol trials; the items analysed were cardigans, shirts, t-shirts, jeans, work trousers and jackets.

Unsurprisingly, the key issue with cardigans was pilling, which affected 83% of items. Pilling tends to make an item of knitwear look aged (Figure 3). Other key problems liable to be reasons for disposal included colour fading (51%) and dimensional stability (34%).

Figure 3. Cardigan with signs of pilling and colour fading.

One of the key problems with shirts, especially if white, was discolouration (54%), either all over or around the collar. Some non-white items (35%) had issues with colour fading. 32% had some kind of fabric breakdown, the collar again being a main concern (Figure 4).

Figure 4. Shirt collar issues.

Pilling and colour fading were key issues for t-shirts. Nearly two-thirds (65%) showed signs of pilling, making the item look worn and old. 51% were faded and 42% had issues with the logo, typically a cracked appearance (Figure 5). 24% showed signs of problems with dimensional stability, mainly looking out of shape.

Figure 5. Logo problem.

In the case of jeans, accidental damage was a key problem, with 51% having some kind of stain or rip unrelated to fabric degradation. 86% were colour faded (N.B. if colour fading was part of the original design, the item was not included). 27% had holes in seams, mainly the crotch, side seam or hem (Figure 6).

Figure 6. Jeans worn at crotch.

Work trousers were analysed as a classic item less subject to fashion trends; the main faults were found to be fabric breakdown (50%) and holes in seams (42%) (Figure 7).

Figure 7. Work trouser with seam damage.

Finally, in the case of jackets (including coats and mackintoshes), colour fading was again the main problem, affecting 50% of garments. The other key issue was holes in seams, mainly in the jacket lining (Figure 8).

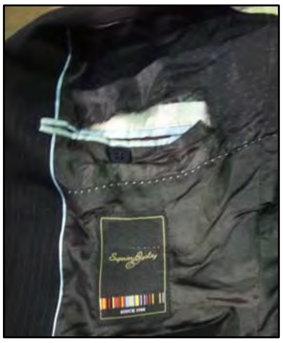

Figure 8. Jacket linings ripped at pocket seam.

Conclusion

Growing interest from the EU and the UK Government in waste reduction has renewed the debate on product life-spans in recent years. In the specific case of clothing, the high volume of discarded items annually has led to increased garment longevity being identified as a means by which companies should reduce their environmental footprint.

The survey results described in this paper suggest that the main explanations for garment failure are colour fading and issues relating to fabric quality. Other common problems are fabric breakdown in the form of fraying and thinning, general wear around the crotch of trousers and jeans, discolouration in white shirts and holes in seams. The industry needs to focus on associated elements of design and manufacture in order to address garment durability.

Companies will benefit by reducing the number of garments failing after a short period because this will result in fewer returns. Such quality management is important but the primary motive behind the research was a need to reduce substantially the large number of garments designed and manufactured in such a way that inevitably results in unduly short life spans.

Implementation of the Clothing Longevity Protocol, an industry-based code of conduct aimed at increasing garment longevity, will require companies to have greater knowledge of the physical faults that lead to garments being discarded. Creating a database with information on the primary causes of garment failure was a first step. Further research will follow in order to identify the measures necessary for change, such as establishing appropriate performance criteria and testing through repeated wash cycle testing and extended wearer trials. Companies will then be in a position to review their performance criteria and testing procedures in order to adjust garment specifications, and to market garments appropriately.

The study was concerned with the durability of garments, their ability to withstand 'wear and tear', rather than the broader concept of longevity. Further research is required to explore garment longevity, which will need to consider the role of the fashion industry, user behaviour and socio-cultural influences upon clothing practices. Major, indeed systemic, change in the sector appears necessary if average garment lifetimes are to increase substantially. The time seems right for stories of quality to be told, user expectations to be raised, and brands and retailers to collaborate and share best practice in order to achieve the necessary change.

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Locating custodial possession in a consumer society

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Keywords: consumerism and the environment; history of consumption; custodial consumption.

Abstract: 'Consumerism' can be seen as an ideological term referring to a relatively new and contested phenomenon, the advent of mass-consumption and its transformative effects in the twentieth century. Social practices around consumption have changed remarkably over the last century, from what might be termed more restrained and cautious 'custodial' forms of consumption, to an expansive individualization, where an accelerated cycle of consumption and discard seems justified in terms of an ongoing process of self-transformation and self-expression.

In this paper I explore some of the key moments and themes in the history of this development from consumption as 'access' to consumption as 'excess', and suggest that since the social practices of consumption are so dependent on social and material contexts, it seems important to look more closely at this historical process, especially at a time when the many of the contexts that once supported overconsumption are coming under considerable political, social and environmental pressure.

Introduction

Consumerism can be defined as 'a state of mind and way of life' where the individual finds meaning and identity through various activities associated with consumption (Smart, 2010, pp. 8-10). But as the history of the term indicates, it has three other overlapping meanings. The first, dating from the early twentieth century, refers to the politics of consumption, and movements like the Consumer Associations which were formed to protect the rights of the consumer against inferior products and services (Hilton 2003). The second, widely used in the interwar period, refers to the still popular economic doctrine that the production of more consumer goods could lead to employment and a rise in the standard of living (Cohen, 2003). The third, widely used in the turbulent politics of the late 1960s, saw consumerism as an excessive attachment to material goods, and blamed this for many larger societal, political and environmental problems (Smart, 2010). This last meaning is still in popular use today.

As this suggests, consumerism is an ideological term referring to what is a relatively new and contested phenomenon, the advent of mass-consumption and its transformative effects on the individual, society, economy and environment in the twentieth century. The four definitions highlight the tensions in its simultaneous promise of access to basic goods and services, its apparent social inequities, its supposed benefit to the economy and society as a whole, and its increasingly serious environmental impacts (Hilton, 2003).

Consumerism seems an especially problematic term now that we must distinguish between more sustainable forms of consumption supporting pro-environmental practices, and various accelerated and intensive forms of consumption with more negative environmental and social impacts (Dauvergne, 2008).

Acceleration and consumption

Changing social and technological contexts during the second half of the twentieth century have had a dramatic effect on the range of objects and services available for consumption, and the speed with which they can be bought, used and disposed of. The German sociologist Hartmut Rosa suggests that three self-reinforcing, interacting forms of acceleration are now in play globally: the first is an acceleration generated by technological innovation and its application in different domains, the second a 'social acceleration' or an increased rate of social change and mobility that this wave of technological innovation has enabled, and the third a more subjective experience of things 'getting faster', which is reinforced by the first two forms of acceleration (Rosa, 2003).

Reflecting upon an essay by the philosopher, Herman Lübbe, Rosa considers this more interior experience of acceleration in terms of a 'contraction of the present', a narrowing of awareness of time created by these social and technological pressures. We are now forced to respond more immediately to others, juggling conflicting demands at home and at work. This results in our living in a sort of extended present, with only the recent past and near future visible to us (Lübbe, 2008).

While Rosa acknowledges that acceleration is the result of an increasing intensification of economic activity dependent on the expansion of corporate capital, he emphasises that this cannot explain its cultural engine, which he terms a universal '*eudaemonic* impulse'. This is a desire for 'the good life' – which I would like to suggest is increasingly made manifest through consumer desire and the choices consumers are daily presented with (Rosa, 2003; and see Dittmar, 2008).

While Rosa hints at the displacement of 'contemplative time' through acceleration's 'contraction of the present', I would add that acceleration also displaces or overrides a slower, more secure relationship with goods and services that once characterized 'normal' consumption practices in many domains. I term this here 'custodial consumption', a more reflective, cautious approach towards all forms of consumption typical of the generation that attained adulthood before the 1940s. Now that we are forced to communicate, read, understand and make decisions more quickly than ever before, our capacity to reflect on what is being decided is clearly diminished (Manzini, 2002).

Individualization in consumption

Many forms of mass-consumption began to intensify and expand following World War Two. This process was led by technological innovations emerging from the War, including the new plastics, electronics and chemical industries, and a dramatic expansion of other older industries, such as car-making (Hilton 2009; Marling, 1998). New forms of consumption developed on the back of this worldwide industrial 'reconstruction', including the more widespread adoption of the car and a series of supporting systems that encouraged the further spread of mass-consumption (Schroter, 2005; Soron, 2008).

The belief of Western governments at this time was 'consumerist', that increasing the production of consumer goods would increase employment and raise living standards. An added bonus was that increasing domestic consumption could give working people, many of them ex-servicemen, the fruits of prosperity and a greater stake in their own nation's democracy (Cohen, 2003; Oldenzeil & Zachmann, 2009). The political strategy followed could be summarised as an attempt to democratize ownership, through making housing, cars, appliances and other consumer goods more accessible to more people. However, this strategy began to falter in the late sixties, and came to a head during the oil crisis of the early-1970s (Marwick, 1998; De Grazia, 2005).

The political conflicts that marked the late sixties were both localized and global in their origins: a growing opposition to the Vietnam War, a growing concern with industrial and chemical pollution, and a concern that mass-consumption, supported by corporations tainted by their involvement in the Vietnam War, was creating more problems than it could possibly solve (Binkley, 2007).

A number of important groups supporting this greater democratization and the social and environmental justice it entailed were formed in the late sixties early seventies. Most shared the belief that through 'consciousness raising' an authentic individual transformation could occur, and then this could be spread by example to the wider society as a deeper social and political transformation (Binkley, 2007). From this perspective, acts of individual consumption seemed profoundly significant, an individual choice with multiple social, environmental and political effects. The *Whole Earth Catalogue* is perhaps the most visible representation of this individualistic, decidedly 'alternative' consumption movement, where new ways of doing everyday things, of producing and consuming, were canvassed, demonstrated and explained, sometimes in great detail (Binkley, 2003).

The Whole Earth Catalogue not only recommended changes in lifestyle but also the use of 'alternative' products and systems (Binkley, 2003). The history of Apple is indicative of how personal computers were initially greeted as one such 'tool' for self-development and transformation, with Apple's famous 1984 advertisement suggestive of the myth of individual liberation and transformation behind this push for an alternative, more self-conscious and liberating form of consumption (Stein, 2002).

Early taken up by Madison Avenue, this type of 'conscious' individualization soon dovetailed into the lifestyle marketing and branding now dominant everywhere (Frank, 1998). This promised transformational change, the products and services being sold as a means of material self-realisation. Seeking out new, more stimulating and gratifying experiences in life's journey of discovery through a changing array of possessions and experiences drew on an 'emotional ontology', as Campbell says, where what 'felt' good became the necessary 'proof' to the consumer of what was needed at any one time (Campbell, 2004).

Custodial consumption

In contrast, those who grew up in the 1920s and 1930s and endured both the Depression and the War had a very different experience of consumption, which was much more closely tied to seemingly fixed and stable needs. This last generation of 'custodial consumers' had learnt to accept the value of 'waste not want not' and to 'make do' with what they had through the experience of Depression and War. In an essay summarising the implications of her work on the social history of waste, Susan Strasser describes a home-based regime of use and disposal involving extensive reliance on repair and recycling, where most household waste was burnt, often in the kitchen stove, and ash, bone and human wastes collected for reuse for local industries and agriculture (Strasser, 2003).

This was a time when consumption was widely understood as providing 'access' to more essential goods and services, and not the pursuit of luxury or 'excess' for self-transformation and self-expression, as is now more common (Crocker 2013). This change in focus and style of consumption is reflected to some extent in the history of advertising, where earlier advertising presented products and services as various means to the 'good life', whereas later advertising increasingly positions consumption in terms of access to luxury, and as an end in itself (Belk & Pollay 1985).

This more custodial generation also had to be persuaded to accept new technological urban systems such as car-based transportation. While in the late nineteenth century most urban landscapes were largely pedestrianized, with mainly bicycles, buses, trams and horse-drawn carts for the majority to deal with, this changed more rapidly and dramatically between the Wars. After the War changes that had occurred in America favouring the introduction of mass-motoring were imported to Britain, Western Europe, Australia, Canada and South Africa, often involving joint ventures with American partners (Schroter 2005; Patterson, 2000).

The troubled history of various government attempts at disciplining pedestrians to remain on the footpath in response to motorization, nearly all of them very unpopular, is suggestive of how modern individualised systems of mass-consumption evolved slowly, often against considerable popular resistance. Moran, for example, notes that Britain's once famous Belushi beacons, one of Britain's first organised attempts at institutionalising pedestrian crossings, suffered from high rates of vandalism as irate pedestrians broke the glass spheres of their flashing lights with airguns or stones. Their outrage was directed at the government's new expectation that they 'must' cross at these beacons, rather than enjoying the freedom of the road as they once had (Moran, 2000).

This now lost world of frugal individual consumption, of strong local relationships and communities, often close-knit and relatively immobile in social and spatial terms, and somewhat ambivalent about their status as 'consumers', was slow to change (Strasser, 2003; Moran 2000). 'Making do', that is managing to live 'decently' with what was available, was a universally admired quality, and 'good housekeeping' its prized companion.

My Father's books

In practice, 'making do' involved a custodial consumption where the shame of wastefulness and 'profligacy' (once a favourite, semi-biblical word of condemnation) was still felt by many, especially those who had suffered some period of scarcity or hardship.

My father, who was born in 1902, exemplified for me this generation in his rather wary regard of shopping, banking and the use of credit. Although for much of his life he enjoyed a generous income from his work, he was clearly a 'custodial consumer' at heart. When he died I remember finding only four pairs of shoes in his house, one of them an old pair of English brogues from the 1950s, probably hand-made in India from an earlier original when he was stationed there after the War. This pair of leather shoes had been meticulously polished and maintained for at least forty years.

His books were another striking example of 'custodial consumption'. A passionate reader, he amassed around 4000 books over his life, and as far as I can tell, never threw any out, only giving away ones he did not like (Cherrier, 2010). He read everything he owned, and inside the fly-covers of many of his books, especially those most valued ones he had bought as a young man in the 1930s when he had little money, he would write short reflections or comments. Some of these he had read many times, returning to old favourites like Gilbert White's *Natural History of Selbourne,* every ten years or so (White [1798], 1932). These books, an extensive collection of classical music in records, and a few water-coloured scenes of the countryside on his walls, preferably without any evidence present of cars, machines or industry, were amongst the few indulgences he spent his money on.

His house was full of references to his own past, and the past of his own family and background, with the furniture all tastefully chosen neo-Georgian style reproductions, that had been popular in the 1920s, with furnishing to match, and almost no references, either visual or material, to the Modernism that so clearly had shaped the modern world. This reference to the past, and its cultural references, was again typical of his generation, who saw in these references a way of asserting their own collective identity, continuity and sense of place (Crocker 2015).

While always careful with his money, my father was still a generous man. He bought his friends fine wines when the occasion seemed to demand it and always entertained well. Loving good quality tea, he insisted on importing Darjeeling from India in small, sweet-smelling wooden boxes, having gained the taste for this in the years he lived there. The idea of teabags horrified him, as did instant coffee. In fact, he also loved good coffee, which he would brew in an old jug, simply hand-grinding the beans and pouring boiling water over them. In his old age he would send me off on regular errands to find an Italian coffee roaster he knew for supplies, long before Australia's café culture had taken hold.

The custodial nature of his attitudes towards consumption, as for many in his generation, came to exist in an increasingly stark contrast to his neighbours, whom I also got to know as a regular visitor to his house (Mackay, 1997). Like many Australians today, these more typical 'Baby Boomer' middle-class consumers were busy working to pay off their debts, renovating their kitchens or bathrooms, going on overseas holidays.

From my father's point of view, as much as he liked these neighbours, they lacked an awareness of the long-term risks overspending involved. 'Caveat Emptor' ('buyer beware') was one of his favourite sayings. Much of the waste that ended in their bins was made up of packaging and spoiled food, something my father and most of his generation would have denigrated as 'bad housekeeping'.

Each week in his bin there was only one small plastic bag of household rubbish, with the cans, bottles and plastics carefully separated and washed. In fact he had grown up at a time when most households had to dispose of their own rubbish, either burning it or burying it, or giving it away to the various collectors that had once been so common (Strasser, 2003). Knowing what to dispose of, and when, for this generation, was again a necessary part of good housekeeping.

My maternal grandparents were very similar in their careful housekeeping and emphasis on quality rather than quantity, and on maintaining what they owned rather than discarding it. Typically, also, at least for those living in Adelaide in the 1940s and 1950s, they grew and preserved most of their own fruit and vegetables, and in my grandfather's case, made and repaired their own furniture on the weekends. Again they avoided borrowing money. My father had no credit card, and nor, even today, does my now aged mother-in-law. My father would always pay for everything in cash or by cheques, which he would offer to bemused tradesmen and bank tellers.

Contexts and contrasts

Custodial consumption is not a particularly mysterious phenomenon, but a series of linked social practices typical of earlier generations, with the last such generation now mostly gone (Shove 2003). It is often overlooked in our quest for solving the larger problems associated with today's overconsumption, and assumed to have been simply a condition of relative scarcity on the more significant road to an emerging 'growth economy'. But this is a mistaken assumption, since what today's 'hyper-consumption' has dislodged from the practices that make up everyday life is highly significant (Lipovetsky, 2011).

While my father's early life included periods of economic hardship, including of course the Depression and War, the culture of self-conscious thrift associated with it was in fact much older, and once typical in different cultures around the world. My father's generation also experienced a much less intrusive printed media, and during the War their inherited culture of thrift was praised and valued by government propaganda and rather falsely, in 'supporting' advertisements. As this suggests, the social shame which now encourages us to spend to 'keep up' with the Joneses, was then deployed to demonstrate one's care and 'good housekeeping' (Dwyer, 2009; Arvidsson).

My father's generation enjoyed a more localised economy, where buyers and sellers knew each other, and often too, knew exactly where the goods they bought and sold came from. This now vanished world had fewer cars, and many more systems that required some collaboration and interaction with others, from relying on the tram each day, to helping absent neighbours cope with the milkman's daily deliveries (Strasser, 2003).

The subsequent post-war 'Long Boom' was dominated by an increasing individualization and technologization of mass-consumption, with more and more products introduced into the home and workplace that had short-lived mechanical and electronic parts, from gramophones to washing machines and cars, and later TVs, computers, tablets and mobile phones (Park, 2010; Slade, 2007). These items could not be easily repaired or maintained, and many in the older generation suffered from a relative ignorance of how these things worked.

The intensification and increasing spread of mass-consumption after the 1970s makes Rosa's theory of 'acceleration' particularly relevant here. Computerization and globalization increased not only the speed of communication, but all commercial transactions and the dynamics of consumption itself (Rosa & Schleierman, 2013). The personal computer and mobile phone brought these changes into the lives of the end-users themselves, displacing many of the slower place-based relationships of the past that had sustained older, established practices of custodial consumption. Many independent artisans involved in repair and manufacturing, for instance, ceased trading at this time, and older-style shops closed; milkmen were replaced by trips to the supermarket, and shopping centres opened everywhere (Marling, 1998).

However, many of the historical contexts that supported the growth of this overconsumption are showing some signs of retreat or structural change: after the Great Recession of 2008 the spending power of those in employment, apart from a relatively narrow elite, have fallen; some Malls in America are in trouble or closed; worries about scarce resources and the increasing stringency of environmental regulations have made many corporations more wary of their environmental impacts; 'down-sizing' has become fashionable, and second-hand trading has become a lively subculture; and there are more and more schemes involving swapping or sharing goods and services (Seyfang, 2009).

Conclusion

I have tried in this little paper to show how today's 'hyper-consumption' is the product of a unique set of historical circumstances that are once more in a state of change. This is not to say that we are going back to the 1930s, but simply that many of the conditions favouring today's accelerated growth or 'throwaway' economy are in a state of crisis and potentially ready for change. Scarce resources, rising fuel costs, unaffordable real estate, environmental anxieties, unsustainable debt levels, and increasing environmental regulations, can all act as drivers of change, encouraging a return to a more custodial style of consumption, where locality, quality, greater durability, recyclability, and repairability are more valued. Product-service systems, demonstrably better for the environment in many situations, are also enjoying a revival (Roy, 2000).

The new communications and information paradigm and the ability to use large amounts of data to ascertain the environmental impacts of a particular object, component or building, perhaps also encourages us to think in terms of interdependent relationships, and a continuing iterative circle of improvement towards forms of production and consumption that are less intensive and destructive (ENOLL, 2015).

To find a better model it is often more useful to examine what has been discarded on the road to our 'high consuming' society, and why, rather than to assume this was simply a 'stage' towards our contemporary situation. De-individualising, normalising and making more affordable and accessible less intensive products and services should be the long-term goal of our pro-environmental strategies, and understanding these as a return to an earlier 'normality' will assist us in a number of ways. For this provides a rich resource of exemplary practices and pro-environmental systems that could well be revived, especially where they can be enabled by contemporary science and technologies.

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Changing average lifetime of buildings over time analysed on the basis of D-based distribution

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Keywords: lifetime distribution; observation year; shipment year; actual lifetime; discard year.

Abstract: We summarised different types of the lifetime distributions on the basis of demolition year, in other word, observation year, which was termed D-based distribution in this study. Lifetime distributions denote distributions of years from construction to demolition for groups of buildings. The D-based distributions are expected to show a chronological change of the whole lifetime of buildings in Japan during emerging replacement in the late 1980s. As expected, we could observe a change on the average lifetime from the years from 1987 to 2010. During an extended boom, we could observe that the average lifetime of buildings steadily decreased due to enhancement of replacement. On the other hand, during a depressed period, it steadily increased. We can conclude that D-based distributions are valuable for analysis on changing the average lifetime which is decided by decisions on replacement.

Introduction

Buildings are constructed, used for a certain period, and then demolished. A dynamic model in the field of industrial ecology is an analytical model which simulates a relationship of numbers of buildings between construction, being in use (buildings stock), and demolition (van der Voet et al. 2002). Similar approaches have been performed in a field of demography and in an application for automobiles, which are named as cohort analysis (Evan 1959) and fleet analysis (Gallez 1994; Dargay and Gately 1999), respectively. A dynamic model can estimate future trends of in-use building stocks and building demolition in scenarios on longer lifetime, change of legislations, and so on (Hashimoto and Terashima 2000). Regarding lifetimes of buildings, it is significant data for conducting material flow analysis (MFA) and life cycle assessment (LCA) (Oguchi et al. 2010; Frijia et al. 2012). In a case of LCA studies, regarding energy consumption and greenhouse gases (GHGs) emissions in a life cycle of buildings, though energy consumption in use phase and GHGs emissions associated with that is dominant, the average of the whole lifetime of the product is generally assumed with very limited evidence on actual lifetime on the basis of observation (Frijia et al. 2012). In a dynamic MFA, time-series annual consumption of materials by end use in the past and lifetime of each end use are used for the analysis. Especially, lifetime of buildings is a key parameter in dynamic MFA studies on steel (Daigo et al. 2006) and wood (Hashimoto and Terashima 2000). In this paper, a lifetime distribution denotes a distribution of years from construction to demolition for a group of buildings. In cases of many types of products, actual lifetime distributions have not been observed (Murakami et al. 2010; Oguchi et al. 2010). On the basis of some cases where actual lifetime distributions were observed, it has been recognised that lifetime of products change over time. For instance, the average lifetime of automobiles in Japan has been increased (Adachi et al. 2005; Oguchi et al. 2010). The average lifetime of mobile phones in Japan has also been dramatically increased after the year 2000 (Murakami et al. 2009). With regard to buildings, time-series change of lifetime has not been analysed.

Many former studies have observed lifetime distributions of a group of products manufactured in the same year. Oguchi et al. (2010) categorised two types of lifetime distributions which are drawn on groups of products which were produced in the same year and which were discarded in the same year. The former and latter types of distributions are named as a construction year based (C-based)

		Base year for which distribution is drawn	
Vertical axis of distribution	Number	*Demolition (discard) year* (a) Demolition-based distribution in number, $\phi_t(x)$	*Construction year* (d) Construction-based distribution in number, $\phi_x(t)$
	Percentage	(b) Demolition-based distribution in percen-tage to total discarded commodities, $d_t(x)$	(e) Construction-based distribution in percentage, $\phi_x(t)/P_x$
		(c) Demolition-based distribution in percent-tage to shipped commodities in correspond-ing shipment year, $w_t(x)$	

Table 1. Types of lifetime distribution. Source: Oguchi et al. 2010.

distribution and a discard year based (D-based) distribution, respectively. We hypothesised that lifetime of buildings in industrialised countries where most of new construction are caused by replacement are decided by situations at the time of demolition. The hypothesis leads to the recognition that actual lifetime distributions of buildings can be observed in the type of a D-based distribution. This study aims to reveal a change of average lifetime of buildings over time on the basis of a D-based distribution.

Method

Basic equation

We employed the basic equation which is well-known in the field of industrial ecology. (Hashimoto and Terashima 2000; van der Voet et al. 2002; Adachi et al. 2005; Daigo et al 2007) In this equation, a condition of constructed floor area, demolished floor area and lifetime of building was described as follows:

$$D_i(t) = \sum_{x \le t} C_i(x)\big(R_i(t-x,t) - R_i(t-x+1,t+1)\big) \quad \text{Eq. 1}$$

where, *Di(t)* denotes demolished floor area of type i buildings in the year *t*, *C(x)* denotes constructed floor area in the year *x*, and *R(y, t)* denotes remaining rate of the buildings which past *y* years after construction at the beginning of the year *t*. Here, the function *R* has a possibility of varying with time of observation, and then has a variable parameter of *t*. In the next section, this point is described in detail.
Here, annual data was used for our analysis due to data availability. In addition, the equation 1 which is expressed in the form of cumulative distribution function can be deformed to equation 2 in the form of probability density function as follows:

$$D_i(t) = \sum_{x \le t} C_i(x) w_i(x,t) \quad \text{Eq.2}$$

where *w(x,t)* denotes the portion of the demolished floor area of buildings which constructed in the year *x* to the total constructed floor area in the year *x*. Note that though the variables in the distribution *w* differ from those used in the distribution *R* for the sake of convenience, dimensions of the variables are same.

Variables *x* and *t* in the distribution *w(x,t)* denote the year constructed and the year observed, respectively. The construction year, *x*, is taken in the x-axis, the observation year, *t*, is taken in the y-axis, the demolished floor area, *w(x,t)*, is taken in the z-axis, and then the distribution shown in Figure 1 could be obtained. As described in Figure 1, two types of lifetime distributions on the planes normal to the x- and y-axes can be defined. One of the lifetime distributions on the planes normal to the x-axis is drawn on the basis of construction year (C-based distribution.) The other one of the lifetime distributions on the planes normal to the y-axis is drawn on the basis of demolition year (D-based distribution.) In addition, the vertical axis can be defined not only as the total floor area but also as percentages to the total demolished one or to the constructed one in corresponding construction year. Those different definitions of lifetime distribution were summarised by Oguchi et al. (2010) as shown in Table 1.

Variables in C-based distribution are valid for a cohort of buildings constructed in each specific year, which vary with changes of factors determined at the time of construction; such as improving design for longer service life, changing regulations, improving strength of materials, and so on. Variables in D-based distribution are valid for buildings demolished in each specific year, which vary with change of factors determined at the time of demolishment; such as revenue from recovered materials, economic conditions, regulations for recycling, and so on. Here after, we analysed time-series

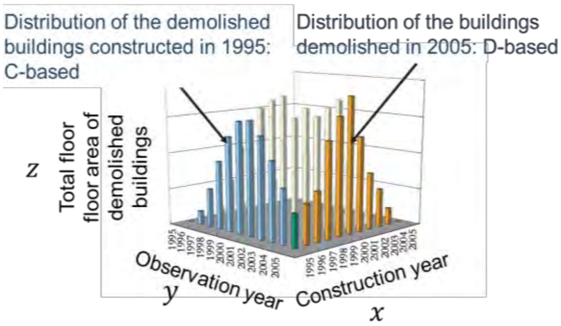

Figure 1 Illustration of lifetime distribution for different base years. Source Oguchi et al. 2010

change of D-based distribution due to focusing on phenomena caused at the time of demolition.

Time-series change of the mean lifetime in buildings

In this study, estimated annual demolished floor area was confirmed with statistical demolished floor area by setting appropriate numerical parameters of the remaining rate *R* for each period. In practical, when *R(t-x, t)* is given, numerical parameters of *R(t-x+1, t+1)* was fitted to meet the condition expressed in equation 3, which is deformed from the equation 1 as follows:

$$\sum_{x\le t}\left(C(x)R_i(t-x+1,t+1)\right) = \sum_{x\le t}\left(C(x)R_i(t-x,t)\right) - \mathrm{D}_i(t) \qquad \text{Eq.3}$$

Here, the parametric functions for *R* were determined by the former research for each construction type and usage (Komatsu 1992) as shown in Table 2. When a numerical parameter is altered, scale parameter or mean value was changed and other parameters were fixed, which could determine the specified parametric function. A schematic diagram for the analytical method was shown in Figure 2.

The remaining rate curve at the beginning of the year *t* shown at right hand side was given, and then the curve for the year *t + 1* shown at left hand side was changed for fitting the shaded area enclosed by two curves with the statistical value.

The former research surveyed the remaining rate at the beginning of the year 1987 which were fitted by parametric cumulative distribution functions (Komatsu 1992). The parametric remaining rate functions were employed for the year 1987, and then the remaining rates for the year 1988 and on were determined year by year.

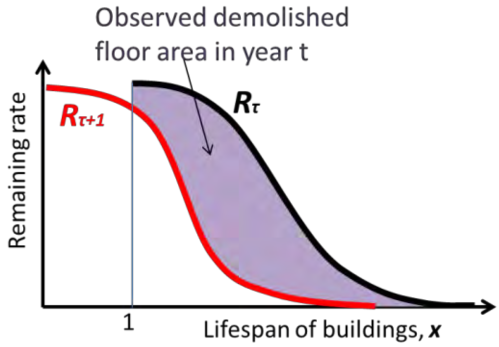

Figure 2. Schematic illustration on a relation between remaining rates and demolished floor area in the year *t*.

Results

The time-series change of mean lifetimes for the three types of D-based distributions, such as φ, *d* and *w*, were calculated. The mean lifetimes for φ and *d* are exactly same on the basis of those definitions explained in table 1. The mean lifetime of steel structured residence in the forms of φ and *d* was changed from 14 years in 1987 to 28 years in 2010. Regarding the lifetime in those forms, a part of distribution curve corresponding to the years when constructed floor area are larger than other periods in the past become relatively higher.

	Distribution function	Parameters*
Wooden residence	Lognormal	$\mu = 3.66$, $\sigma = 0.633$
Steel framed residence	Weibull	$m = 6.75$, $\eta = 64.4$, $\delta = -28.4$
Steel framed non-residence	Weibull	$m = 3.13$, $\eta = 40.4$, $\delta = -7.33$
Reinforced concrete structure residence	Weibull	$m = 3.09$, $\eta = 61.2$, $\delta = -3.74$
Reinforced concrete structure non-residence	Lognormal	$\mu = 3.55$, $\sigma = 0.390$

* Numerical parameters for Weibull distributions; m, η and δ, denote shape parameter, scale parameter and location parameter, respectively.

Table 2. Classification of buildings in this study on the basis of structure and usage. Source: Komatsu 1992.

Then, the mean lifetime of the distribution was put weight on the years. Our results were weighted on buildings constructed after 1970's because constructed floor area has been remarkably increased in 1960's and 1970's in Japan. Therefore, the estimated mean lifetime was monotonously increased during the estimation period. The estimated mean lifetime at the year 2010 was about 30 years, which indicates that the buildings constructed in the year 1980 which is 30 years ago from 2010 was dominant in buildings demolished in 2010.

In the lifetime distribution in the form of *w*, the mean lifetime of steel structured residence was changed from 24 years in 1987 to 37 years in 2010. In this form, the time-series change of constructed floor area does not distort the distribution because the demolished floor area was divided by constructed floor area in the corresponding year. Meanwhile, although the total of a probability distribution must be one in general, the total of the demolition rates in the distribution of *w* not necessarily correspond to one because denominators of each rate are different. Consequently, the mean lifetime was estimated to be relatively short in the observation year when the total of demolition rates was less than one. The estimated mean lifetime in the form of *w* was sensitive to the total of demolition rates.

The new definition of D-based distribution could be defined as the fourth possible form, which was obtained by differentiating R with respect to the age of buildings. The distribution was defined as *r*–type distribution. The *r*–type distribution expresses the expected lifetime of a building demolished at the beginning of year t. The mean lifetime on the basis of *r* might be the appropriate index for assessing the mean lifetime at the time point of observation, that is, among four types of D-based distribution. The mean lifetime is influenced neither by past annual change of constructed floor area nor by demolition rates. Time-series changes of mean lifetimes estimated on the basis of *r*-type distribution are shown in figure 3 by construction types. The mean lifetimes of each type of buildings decreased until early 1990's, and from then on increased. It is considered that a booming economy let the lifetimes become shorter due to active renewals during the late 1980's to 1992 in Japan.

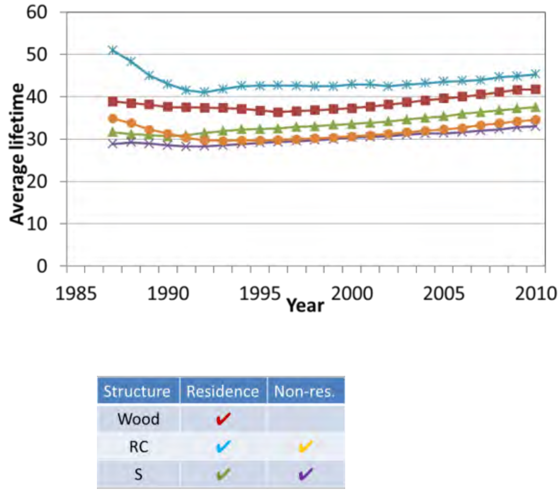

Figure 3. Time-series changes of mean lifetimes of buildings on the basis of *r*-type distribution by construction types.

Conclusions

We summarised four different types of the lifetime distributions on the basis of demolition (observation) year, which was termed D-based distribution in this study. The fourth one was newly added by this study to the former study (Oguchi et al. 2010). We found that the lifetime distribution in the form of the fourth type, *r,* is the most suitable for observing time-series change of mean lifetime in D-based distributions.

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Fast fashion, quality and longevity: a complex relationship

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Keywords: fast fashion; quality; longevity.

Abstract: The findings of a systematic literature review on fast fashion and quality are presented. The key findings are that: (i) the term quality is predominantly used in the literature to refer to the perceived intrinsic quality of products; (ii) there is little supporting work which assesses the objective intrinsic quality of fast fashion products and, particularly, a lack of evidence that this differs for high-street contemporaries; (iii) there is a growing body of literature on the environmental and social impact of process-oriented qualities for fast fashion which contribute towards credence quality dimensions. Social impacts of fast fashion are well documented, but studies do not address whether these are significantly worse than other mass-market retail models. There is evidence that fast fashion has significant environmental impact throughout the entire product lifecycle, largely as a result of the decreasing lifetime of the products. However, the relationship between decreasing lifetime and intrinsic quality attributes is largely anecdotal; and (iv) extrinsic quality attributes are the subject of several fashion marketing studies, but their relationship to initial product life has not been robustly explored.

Introduction

The UK mass media is increasingly focused on environmental and social impacts of the production and disposal of fashion goods. The discourse on the fast fashion phenomenon is particularly critical, describing the outputs variously as 'throwaway' (Tibbetts, 2008), 'shoddy' (Hickman, 2009) and 'poor quality' (Watkins and Masters, 2013). It is commonly implied that 'shoddy' fast fashion products are increasing the volume of textile products discarded yearly (Beattie, 2008).

In writing this paper, the authors are not intending to act as endorsers of fast fashion, which is indeed of concern from environmental and social perspectives. However, in reviewing the academic literature, we have become increasingly concerned that there is little robust exploration of the relationship between fast fashion, quality and product longevity. Moreover, there is little consensus on what constitutes fast fashion and what designates quality.

This paper reports the findings of a systematic literature review which sought to identify what is currently understood about fast fashion and quality and propose future directions for research.

Method

A systematic literature review was carried out according to the methodology described by Seuring and Müller (2008). The Boolean operators 'fast fashion' and 'quality' were used to search a well-known academic database with access to thousands of peer-reviewed journals. The initial search produced 220 articles. Key aspects of what constitutes fast fashion were synthesized to provide a working definition, which was used to narrow down the literature. Articles were included in the literature review if they met the following criteria:

- The main body of the article specifically referred to quality
- At least two of the following features were evident in the business and retail model: speed-to-market processes in production and retail; short product shelf life; aimed at the youth market; and are focused on fast fashion brands, according to the wider literature consensus.

Descriptive analysis

Sixty-five peer reviewed journals published between 1998 and October 2014 were considered. The bulk of literature is from the period 2006 – 2014. Since 2006 there has been a consistent level of interest in the topic, with a median of 5.3 papers published yearly. In 2013, the number of papers published climbed to twelve due to the publication of a special issue on fast fashion by the *Journal of Fashion Marketing and Management.* Although the *Journal of Fashion Marketing and Management* was the most common source of publications relating fast fashion and quality, the subject matter has broad appeal, with articles being published in thirty-one different journals ranging from the *Journal of Corporate Citizenship* to the *Journal of Economic Geography*.

Definitions of fast fashion in the literature are both narrative (58% of the papers describe characteristics of the systems and products) and exemplary (69% of publications provide typical company names). Zara is the most commonly cited example of a fast fashion brand.

Quality attribute framework

Quality is an ambiguous concept that may be broken down into a number of dimensions. In this study, we use a modified form of the quality attribute framework developed by Fandos and Flavián (2006) in their study of product of designated origin (PDO) foods and apply it to the fast fashion literature. Figure 1 summarises the quality attribute framework.

Findings

Disciplinary representations of fast fashion and their relationship to quality attributes

Fast fashion has attracted attention from diverse academic disciplines, but these may be synthesized into four main representations. The literature variously considers fast fashion from the point of view of: strategic operations management; strategic retail management; consumer experience; and ethics. Different

Figure 1. Quality attribute framework. Source: adapted from Fandos and Flavián, 2006.

quality attributes are relevant to each representation.

Factors typically discussed in strategic operations management include just-in-time and leagile supply chains (Bergvall-Forsberg and Towers, 2007; Lopez and Fan, 2009), other aspects of global sourcing (Doyle, Moore and Morgan, 2006) and strategies for quick response to consumer demand (Bhardwaj and Fairhurst, 2010). Relevant quality attributes are, unsurprisingly, industry-facing, process-oriented and objectively measureable. In effect, the quality of fast fashion business operations can be defined in terms of the efficiency of the supply chain; getting the right product to the right customer at the right time and the right price.

In strategic retail management studies have explored product category management (Dewsnap and Hart, 2004), retail environment (Byun and Sternquist, 2008), traffic patterns, footfall and staff selection (Newman and Patel, 2004). The dimensions of quality applicable here are those related to service quality.

Within the consumer experience literature, brand perceptions (Cheng, Hines and Grime, 2008), purchase decision-making (Watson and Yan, 2013), use experience (Gabrielli, Baghi and Codeluppi, 2013) and disposal decision-making (Joung, 2014) have all received academic attention. Whilst both objective and perceived quality attributes are relevant here, perceived quality attributes related to service and experience predominate. These may be further broken down into the intrinsic and extrinsic attributes affecting consumer behaviour.

Ethical issues include human rights abuses in the supply chain (Taplin, 2014) and environmental impacts throughout the product lifecycle and particularly at disposal (Fletcher, 2010; Claudio, 2007). Many quality attributes are relevant here: objective process-oriented quality analysis can reveal supply chain issues; objective product-oriented quality and consumer-facing experience quality can support the arguments that it is the 'shoddy' nature of fast fashion which precipitates its disposal.

Ethical issues are also examples of credence quality attributes; whilst there is evidence in the literature that consumers are concerned about environmental and social impacts of fast fashion, there is limited evidence that it is having a significant impact on macro-level purchase behaviour (Kim, Choo and Yoon, 2013).

Prevalence of articles concerned with perceived quality attributes

Just over half the papers surveyed discussed the perceived quality of fast fashion products. Most papers reviewed address perceived intrinsic quality attributes of the product. These studies tend to employ small-scale convenience sampling methods and report qualitative findings (Birtwistle and Moore, 2007; Carey and Cervellon, 2014; Watson and Yan, 2013). The most common methods for data gathering are surveys, individual interviews and focus groups and are geographically localised. Most participants in the studies fall into the typical age range for fast fashion consumers, offering the potential for broader meta-analysis. Meta-analysis of existing studies could draw out existing trends and inform design of future studies.

Perceived intrinsic quality attributes may be cued at point-of-purchase and during wear. In the case of point-of-purchase, literature around consumer decision-making notes that consumers are willing to trade-off perceived intrinsic quality against price, an extrinsic quality attribute (Gabrielli, Baghi and Codeluppi, 2013). In the broader literature on quality attributes, most studies have found a positive relationship between price and perceived intrinsic quality (Lee, 2012). This assumption that 'the higher the price, the better the quality' is explored by Cheng *et al*. (2008), who note a difference in perceived identities of two high street fast fashion retailers with different pricing strategies. Extrinsic service-quality related attributes are also at play at point-of-purchase, such as fashionableness, availability and brand perception (Cheng, Hines and Grime, 2008; Choi, Lui, Lui, Mak and To, 2010; Hennigs, Wiedmann, Behrens, Klarmann and Carduck, 2013; Newman and Patel, 2004). However, these are rarely referred to in discussions of quality. This raises a question as to how researchers define quality. Only eight papers attempt to define quality and there is no consensus between them. It is therefore difficult to ascertain what consumers understand when asked to discuss the quality of fast fashion. This becomes particularly relevant when addressing the issue of longevity. If extrinsic quality attributes experienced in the purchase process contribute more to purchase decision than perceived intrinsic quality, we may hypothesise that the discrepancy between search quality and experience quality is such that the product ceases to satisfy the user rapidly. It is important, then, that the relative balance of quality attributes in the consumer decision-making process is explored within the context of product longevity.

Product longevity is also influenced by another intrinsic quality attribute – that of design, or style. Style obsolescence is a well-known concept and is central to the fashion industry. In articles examining disposal habits of fast fashion consumers, style obsolescence is a commonly cited reason for disposal (Bianchi and Birtwistle, 2010; Birtwistle and Moore, 2007; Joung, 2014). However, it is worth noting that there are a number of end-of-life options for fast fashion consumers, and the choice will affect product longevity. Analysis of clothing disposed via different mechanisms has shown that there is positive correlation between intrinsic product quality attributes and consumer interaction with the disposal process (Morley, McGill and Bartlett, 2009). For example, a garment that is damaged or stained is more likely to be donated anonymously to household waste recovery sites than taken to a charity shop. However, no such analysis has explored the relationship of disposal choices to intrinsic perceived quality attributes. Understanding how these affect the consumer's concept of value at end-of-life is central to developing systems for enhancing fast fashion product longevity.

Objective and perceived intrinsic quality

Meanwhile, there is a dearth of evidence on the objective intrinsic quality of fast fashion products. In other words, whilst consumer perceptions of product quality are often explored, objective assessment of material and construction quality is lacking. A single paper was identified that undertook rigorous testing of fast fashion products (Fowler and Clodfelter, 2001). A second paper explored the relationship between expert perceptions of quality and technical performance (Apaegyei, McLoughlin and Omidvar, 2013).

In both cases, the product choice highlights the complexity of assessing intrinsic product quality for the fast fashion market. Whilst a particular brand is often defined as fast fashion, not all the products they offer have a short shelf life or are brought rapidly to market (Tokatli, 2008). Indeed, many retailers operate a variety of supply chain models, dependent on the product; for example, true fast fashion products constitute the minority of Zara's retail mix (Lopez and Fan, 2009; Romano, 2009). For products designed to meet immediate market demand, lead times are short, and it has been suggested quality assurance processes may suffer as a consequence (Barnes and Lea-Greenwood, 2006; Tokatli, 2008). In the case of basic products, longer lead times would suggest that quality assurance processes are not compromised; however, in these cases quality may be affected by other measures designed to reduce costs, particularly raw material selection. Therefore, modes of failure may differ between basic and fast products. In existing studies, selected products (cargo pants and T-Shirts) fall into the basic item category.

A second point raised by the small number of technical studies is the indicative lack of relationship between product price and objective intrinsic quality. Fowler and Clodfelter (2001) compared products form two different price points in the market. No significant difference was seen in terms of objective intrinsic quality. In an industry where suppliers are working across different market sectors, this finding is unsurprising. Nor is the lack of correlation between objective intrinsic quality and price unusual. Previous research exploring the relationship between price and objective quality measurements shows that (in spite of strong relationships for some products) across categories the correlation is low, and sometimes even negative (Burton and Lichtesnstein, 1990). However, it has been asserted that the low quality of fast fashion products leads to their rapid disposal (Bianchi and Birtwistle, 2010; Joung, 2014), with no discrimination being made with regard to perceived or objective aspects. Further testing is necessary in order to determine whether products produced by fast fashion brands truly are of inferior intrinsic product quality to similar product categories from other high street retailers, and, indeed whether intrinsic product quality variability across a brand's retail mix may be related to differences in supply chain design.

Process-oriented quality attributes and credence quality attributes: fast fashion and ethics

Fast fashion brands are often singled out for criticism for their environmental and social impacts (Arrigo, 2013; Claudio, 2007). There is a clear relationship between documented social impacts of fast fashion and supply chain optimization. Ensuring agility, responsiveness and resilience in a supply chain is typically achieved through flexible relationships with suppliers; cost benefits can be realised by sourcing from low labour cost countries. In the early days of fast fashion, leading companies kept supply chains local; however, geographic locality is no longer a necessity for quick response (Tokatli, 2008). The globalised supply chains in the fashion industry are notorious for unethical working practices: forced overtime; child labour; health and safety breaches; and myriad other abuses of the workforce. High profile issue such as Rana Plaza and the plight of Uzbekistan cotton farmers are factors which contribute to fast fashion avoidance (Kim, Choo and Yoon, 2013) and are credence quality attributes for fast fashion consumers (there is a significant attitude-behaviour gap for some fast fashion consumers). However, it should be noted that the rate of change of fashion has increased across all market sectors in recent years and we are yet to identify any rigorous study comparing the social impacts of different mass fashion business models.

Environmental impacts occur throughout the lifecycle of a fashion product, but the fast fashion industry is particularly criticised for waste issues related to the short lifetimes of the product. Ironically, although the low quality (by which we mean objective intrinsic quality) of the fashion products is often held responsible, it appears that performing well against process-oriented quality attributes and retail-oriented service quality attributes (i.e. being able to produce a cheap product in response to rapidly-changing consumer trends) may have a negative effect on perceived intrinsic product quality attributes and contribute to short lifetimes and sub-optimal disposal decision-making.

Recently attention has turned to activities being undertaken by fast fashion companies to address these criticisms. Studies have been undertaken on the corporate social responsibility activities of fast fashion brands (Arrigo, 2013; Hvass, 2014) which provide evidence of actions being put in place to reduce environmental and social impacts.

With regard to product longevity, slow fashion (Fletcher, 2010) provides a model for the system-level change that is needed in fashion to fully address the environmental and social impacts of short product lifetimes; however, wholesale systemic change is a slow process. In the meantime, more incremental approaches to reducing the environmental can deliver benefits for fast fashion brands. Extended producer responsibility (EPR) models have been proposed in which the company operates material stewardship over short initial lifetime products (Hvass, 2014; Niinimaki and Hassi 2011). EPR may, if implemented appropriately, allow for a more systemic approach to lengthening product lifetimes.

Conclusions

In reviewing the literature around fast fashion and quality relationships, we have found it difficult to find robust evidence of how the different quality attributes impact on product longevity. This requires greater elucidation if products and systems are to be designed to lower the environmental impact of fashion products. It is particularly ironic that, whilst criticism of the low quality of the products is usually based on objective intrinsic quality attributes, it may be the good performance against other quality attributes that drive short product-lifetimes.

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Analysing impacts of product life extension through material flow analysis: the case of EEE and paper

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Keywords: Material Flow Analysis; WEEE; paper flows; extension of product life; policy interventions.

Abstract: Material consumption is an important driver for environmental pollution. Total material throughput can be reduced through the extension of product life. The paper suggests Material Flow Analysis (MFA) as a method to assess the potential material throughput reductions due to increased product longevity. The method is applied to the case of Electrical and Electronic Equipment (EEE) and paper products. The paper first collates data from different sources to give an overview of material inputs and outputs for both material/product categories in the United Kingdom. Subsequently, it reviews the literature for a selection of interventions and calculates the potential savings in the total material throughput. For EEE, the analysis emphasises the issue of optimal life times that need to balance the impact generated in the production phase and during the use of the product. For paper, a key issue is the practical limitations on reusing a material that is easily damaged and worn. It is concluded that there is considerable potential for MFA in estimating the impacts of product life extension on material throughput although limitations in data availability and quality are acknowledged.

Introduction

Material consumption is associated with important environmental impacts (Fischer-Kowalski and Swilling, 2011). In the United Kingdom only, annual consumption is estimated at around 600 megatons, about 40% of which is discarded as waste (Eurostat, 2015a, 2015b). Much of the policy emphasis has been put on recycling but extending the use life of products, and also of the materials contained in them, could play an equally important role in reducing the environmental impacts of consumption and the preservation of natural resources.

Longevity can be understood as the interval between the point in time where the products come into the market to the point in time where they are discarded and turned into waste. Longevity can play an important role in reducing consumption and waste, but it is little understood, since it relates to dimensions of design, business models, manufacturing, behaviour, waste management, and many different factors and drivers. Material Flow Analysis (MFA)[1] can help understand some of these aspects.

This paper analyses two main areas of concern: electronic and electrical equipment (EEE) and paper and paper products. The consumption of EEE is on the rise globally, especially in developing countries. The amount of discarded computers in China and South Africa is expected to increase with 500% in 2020 compared to 2007 levels (Schuelp et al., 2009) and substantial increases are also expected in other emerging economies (Wang et al., 2012). In the United Kingdom, the EEE market has grown rapidly in the last years and waste arisings have increased correspondingly (Eurostat, 2015c). EEE contain important valuable metals, such as copper, and critical metals, such as palladium (He et al., 2006; Reck and Graedel, 2012). They also contain many hazardous substances that can lead to important health and environmental risks if improperly managed (Huang et al., 2009).

[1] Abbreviations used in this article: Electrical and Electronic Equipment (EEE), Global Warming Potential (GWP), Life Cycle Assessment (LCA), Material Flow Analysis (MFA), Waste Electrical and Electronic Equipment (WEEE).

Paper is a relevant material given its high impact in terms of life cycle carbon emissions and its high annual conversion rate into waste compared to other important material categories such as steel and plastics (Allwood et al., 2010). At the same time, paper is generally perceived as a success story in terms of recycling, with the European recycling rates being at around 70% (CEPI, 2012), and is a role model for the sharing economy in the form of libraries. Environmental impacts of paper include carbon emissions and dioxins released during production as well as methane emissions from landfills.

This paper aims to show the utility of MFA for assessing the impact of longevity on total material throughput by applying tailored MFAs to two case studies representing very different material/product categories. The paper has been structured as follows. Section 2 reviews some of the literature on longevity and section 3 explains MFA. Section 4 analyses material flows and suggests interventions for EEE and paper. The article wraps up with discussion (section 6) and conclusions (section 7).

Method

The paper uses Material Flow Analysis to link specific practical interventions to reductions in total throughput. Material flow analysis is a systematic assessment of flows and stocks within a predefined system (Brunner and Rechberger, 2004). The results of MFA are commonly visually presented in Sankey diagrams, which have their origins in thermal engineering, and that provide a tool to compare actual flows with desired flows in a visually intuitive way (Schmidt, 2008).

Extended use life is the delay between the time point when the product entered the market and the time point at which the product becomes waste. This has a number of implications in terms of waste management as waste arising will depend on the lifespan distribution of different products and the material composition of waste, especially for products with longer than average use-life and those that have undergone substantial design changes over the years (for example in the concentration of hazardous substances).

In addition, longevity or the extension of average use life has also other important implications in terms of potential savings of virgin raw materials and the transition to more circular models, where resources maintain their prime function for longer and are recycled at the end of the use life to recover valuable resources contained in them. Extending product life thus affects both virgin inputs, waste outputs, and material throughput of the economy.

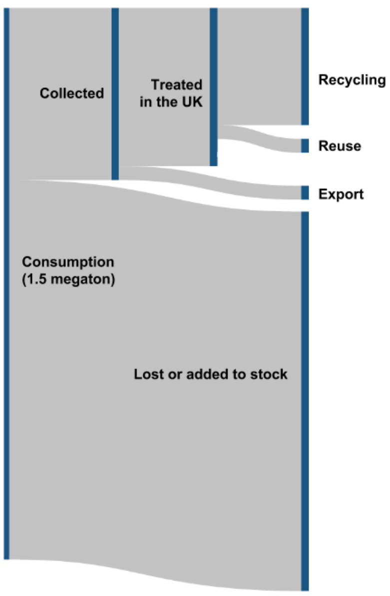

Figure 1. Sankey Diagram of EEE/WEEE product flows in the UK in 2010. Source: own elaboration based on Eurostat.

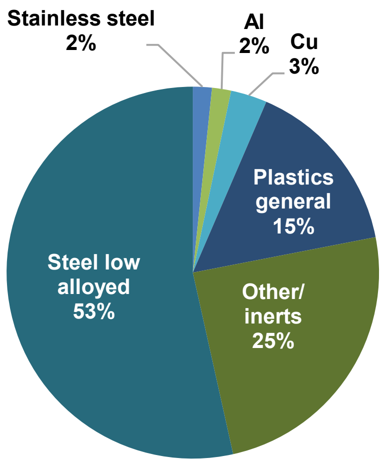

Figure 2. WEEE Material composition in the UK 2010 for large household appliances. Source: own elaboration based on WRAP, 2012 and Eurostat.

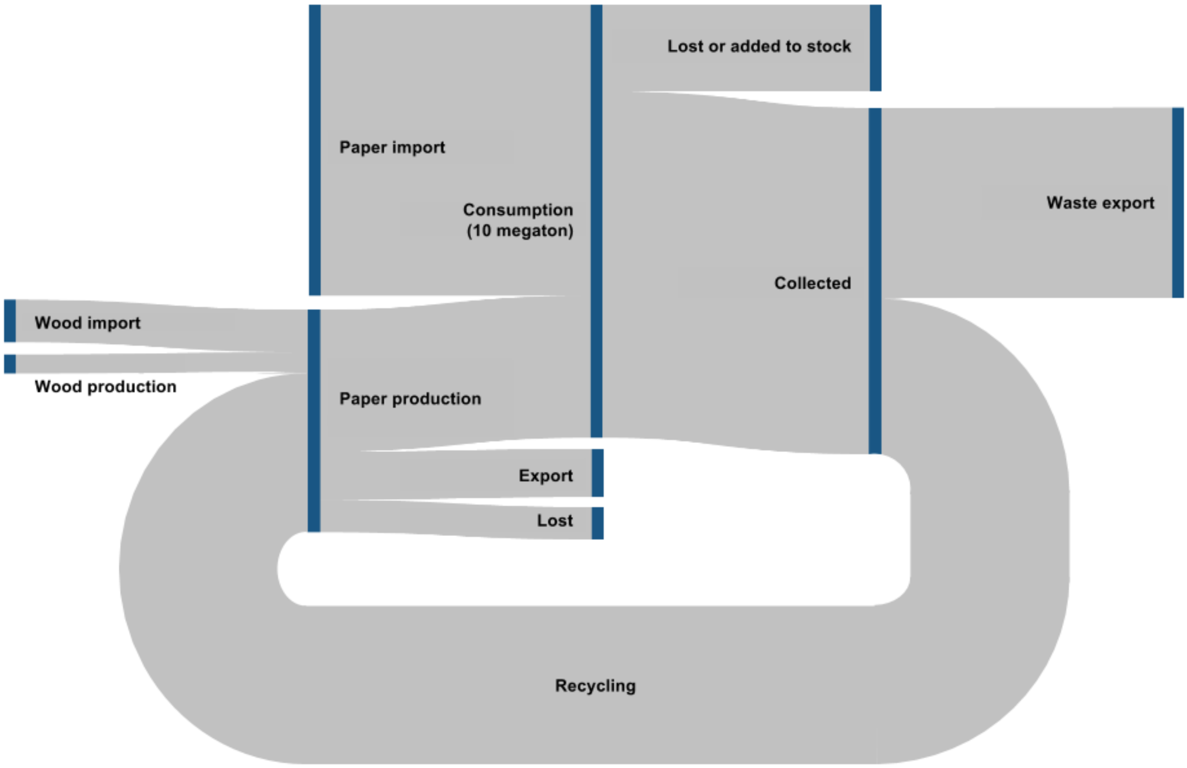

Figure 3. Paper flows in the UK in 2012 (Source: own elaboration based on PPL (2012) and Eurostat).

Analysis

This section presents the findings from the MFA for EEE and paper and paper products. It subsequently discusses potential interventions for extending the life of products and calculates their impact on resource throughput.

Electrical and Electronic Equipment (EEE)

Material flow analysis of EEE

Figure 1 depicts the material flows for the UK for 2010 [1]. The lifespan distribution is not considered. The diagram shows a big discrepancy between the weights of the products put on the market and WEEE collected. Even in the absence of a lifetime distribution of products, this seems to point to a large quantity of materials that are either collected together with mixed household waste, exported as second hand goods, hoarded or just illegally dumped. Only in the first case, that WEEE undergoes appropriate treatment.

Figure 2 provides an idea of the material composition of EEE/WEEE for the category large household appliances, based on the combination of WEEE data and material composition data. Material composition data has been obtained from the literature and a WRAP study published in 2012 EEE (Huisman et al., 2007; Wrap, 2012). The data has been compared with other literature sources on material composition for other developed countries, significantly Japan, to check for consistency (Oguchi et al., 2013; Tasaki et al., 2007), although a sensitivity analysis has not been undertaken as it is out of the scope of this paper.

Interventions in the EEE cycle

Extending first use life: extending warranties

Extending the technical use life of large household appliances could bring important reductions in the throughput of the UK. Extending first use life needs to consider the potential trade-offs between material saving and energy consumption, as it is expected that new appliances would be more energy efficient.

[1] Please note that in some cases data from 2009 has been used, as it is the last available for a number of variables.

Kim et al. (2006) have looked at the optimal life time of fridges taken into account this trade off. According to their analysis, optimal lifetimes for fridges ranged from 2-7 years for the energy objective and 2-11 years for the Global Warming Potential (GWP) based on Life Cycle Assessment (LCA) and dynamic programming. Also, given that energy efficiency has improved substantially in recent years, it is expected that optimal life has increased as the marginal energy efficiency improvements are expected to reduce over time.

In order to avoid potential trade-offs between energy and resource efficiency this intervention would have to consider introducing changes in the design of fridges and increasing modularity and upgradability. This intervention could significantly reduce demand of primary resources and waste generation.

Given that the average life of fridges is around 11-14 years (Bakker et al., 2014; Oguchi et al., 2013), further research is needed to assess the desirability of prolonging the use life of these type of appliances if we consider energy implications. However, if we consider that 8-10% of large household appliances break within the first 5 years due to early failure of some of the components (Oeko-Institut, 2015), extending warranties to five years for all large household appliances and ensuring the availability of replacements for a longer period of time could bring material savings of around 70 kilo-tonnes, and saving of approximately 4.5% of the total material throughout. This savings could be in the region of around 85 kilotonnes if we also consider small household appliances, and around 5.5% of the total material throughput.

Extending the total use life: upgradability of products

Another approach to extent the total life time of EEE would be extending the second use life of the appliance through repair, reuse and remanufacturing. Although there is very little research on the opportunities to increase reuse and repair of fridges, a recent study by WRAP considered that about 23% of the discarded appliances could be reused with very little repair. Again here the issue of the trade-offs between energy and resource efficiency need to be considered.

A 23% increase in the reuse of large household appliances such as fridges could bring material savings in the region of 160 kilotonnes, and about 10% of the material throughput. This though requires of the establishment of well-developed repair and reuse networks that provide guarantee to the consumer about the safety and performance of reused goods.

Remanufacturing, reuse and recycling of components

The third proposed intervention looks at extending the life of the components through remanufacturing and recycling of materials and use as a source of secondary materials. A study on appliance remanufacturing and energy savings estimated that total raw material processing and manufacturing of a mid-size fridge required 4,442 MJ to 6,847 MJ. Driven by legislative pressure. the energy consumption of fridges during the use phase have varied considerably ranging from 180 GJ for a model in 1974 to 50 GJ for a model in 2008 (Boustani et al., 2010)

The same studies concluded that remanufacturing would indeed have been a more energy consuming option since 1974 up to 2001. During this period, important increases in energy efficiency outpace energy savings associated to raw material processing in the remanufacturing. The study, however, also points that when comparing a 2001 and 2008 model, the energy savings of remanufacturing would break even with the energy savings associated to energy efficiency of newer models, given the slower pace of improvements. A 20% increase in the remanufacturing of large household appliances could bring material savings of about 140 kilo-tonnes and about 9% of the total material throughput for EEE.

Paper and paper products

Material flow analysis of paper

The calculation of the paper flows is based on waste data, production and consumption data, and forestry data. Figure 2 shows the paper flows for the United Kingdom in the year 2010 including imports, exports and a recycling loop. The Sankey diagram uses the waste generation and treatment data from Eurostat, supplemented with industry statistics (PPL Research Ltd, 2012) and a government publication on forestry and paper (Forestry Commission, 2011). Most of the paper consumed in the UK is imported and some of the domestic production is exported. A roughly

equal proportion of paper waste is exported and domestically recycled.
The Sankey diagram reveals a relatively large discrepancy between inputs and outputs to production. This is probably due to the inputs being measured as green tonnes (including water) of imported pulp and wood. Also, some of the paper waste generated in production might not be accounted as such but instead as mixed wastes. The small discrepancy between inputs and outputs of the consumption phase represent two things: additions to stock and unaccounted paper waste that may be found in "mixed waste" flows in Eurostat. The data does not allow distinguishing between the two options.

Interventions in the paper cycle

Lending and second-hand buying of books

Books are among the most popular goods to be shared or sold second hand. According to a study by Maki (1999), as cited by (Heiskanen and Jalas, 2003), library books in Finland are used 60 times on average and constitute a saving of 32.000 tonnes of paper compared to the alternative of new sales. If libraries in the UK where to increase their stocks, the average amount of users may increase when it concerns top titles (which are currently easier to get by buying them) or if they expand into more marginal categories. Either way there is a large potential for dematerialization in the book sector through the extension of libraries.
If the number of 60 is valid, then total physical UK book sales could be reduced with 50% by only increasing the annual purchases of public libraries with about 20%, assuming privately held books are read only once.

The best weight estimate for an average paper book is suggested to be 600 grams (Borggren et al., 2011) and the total consumer sales in 2010 is estimated to be 339 million copies (The Publishers Association, 2012). Consumer books make up 1.8% of the total mass flow of paper in the United Kingdom. An increase of library stocks with 20% and an associated reduction of consumer book sales with 50% could thus reduce the overall paper flow with about 0.9%. The practical potential would however be much lower.

Un-printing office paper

For office paper, promising advances have been made regarding the "repairing" of paper through un-printing technology. Un-printing may involve the use of special ink or paper although a laser ablation process has been shown to work on regular paper and ink.
The potential for un-printing to reduce material throughput seems very high. For the "e-blue" technology (Counsell and Allwood, 2007) estimate that un-printing could reduce energy use and carbon emissions with 86% and 95% per tonne of office paper. This reduction is realized because all other stages in paper production can be cut out. With the latest technology, that allows un-printing up to five times, the throughput of office paper could potentially be reduced with 80%.

The consumption of cut size paper is about 5% of total paper and board consumption (PPL Research Ltd, 2012) and about 75% of cut size paper is used in offices (Hekkert et al., 2002) where such technology could be easily installed. The share of paper suitable for un-printing is thus around 4% and un-printing could reduce the total paper flow about 3% if paper were to be un-printed about five times on average.

Extended use of paper packaging

Paper packaging is a notoriously difficult to reuse since it is easily damaged in the process of use. Yet paper is a popular packaging material. About one third of the total packaging waste stream in the United Kingdom consists of paper (Eurostat, 2015d). For instance for white goods the share of paper in packaging material can range from 16% to 77%, with large appliances like freezers consistently featuring more than a kilogram of paper packaging per product (WRAP, 2007).

One way to increase the lifetime of packaging is by replacing paper packaging by more durable plastics packaging, especially in non-consumer environments. However, when consumers are involved, paper is often preferred because of its aesthetic qualities; research suggests that consumers associate paper bags more strongly with an attractive appearance than plastic bags (Prendergast et al., 2001). Based on the same survey in Hong Kong, the article suggest that paper bags are in fact more likely to be reused than plastic bags.

The potential for reuse of paper packaging is very difficult to assess. Uniquely shaped and printed paper packaging has little potential for reuse, generic boxes and board (from for instance furniture packaging and appliances) may in fact be reused for slightly varying purposes, and paper bags could be used many times to carry different things. The durability of the packaging is key, as well as the print, which could influence reuse depending on "fashionableness" of the depicted brand.

Most studies on environmentally friendly packaging however suggest the replacement of paper packaging by reusable plastic packaging. Such plastic packaging has lower environmental impacts when used once. A study of different types of shopping bags in China, Hong Kong, and India showed that paper bags had the highest life cycle carbon impact. At the same time, the authors point at reuse as an opportunity for significant reduction of carbon impacts (Muthu et al., 2011). As such, when it comes to carbon emissions, paper packaging can only compete with plastic alternatives if it is reused significantly more than plastic alternatives.

Conclusions

This paper has studied the potential for using material flow analysis for assessing possible reductions in total material throughput through the extension of product life. In particular, it assessed the potential of increasing product longevity for the case of Electrical and Electronic Equipment (EEE) and paper products. The analysis shows that there is considerable potential for MFA in estimating the impacts of product life extension although more data is needed.

The paper first used data from different sources to give an overview of material inputs and outputs for both material/product categories. Subsequently, it drew on the literature for a selection of interventions and calculated the potential savings in the total material throughput. For EEE, a key issue was the idea of optimal life times based on pollution caused by the production and use of the product. For paper, a key issue are the practical limitations on reusing a material that is easily damaged and worn.

The conclusions are two-fold. First, it has been shown that certain interventions are likely to reduce material throughput for EEE and paper and could thus reduce environmental pollution. Second, the use of material flow analysis has proven fruitful in calculating the potential material throughput savings for the interventions. Further work should focus on the collection of more detailed data for mixed waste streams and EEE exports, demand substitution, and other product and material categories than EEE and paper.

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Objects are actors too: the 'hack-a-thing' workshop series as a case for revising new user-object relationships

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Keywords: hacking; Actor-Network Theory; user-object relationships; infrastructuring processes; FabLab.

Abstract: In this paper, we explore if introducing local youth to the context and opportunities of a FabLab (Gershenfeld, 2005), via 'Hack-a-Thing' workshops, could allow them to imagine new relationships between themselves and their surrounding objects via, for instance, teaching them new, particular skills (e.g. in hacking) and/or altering their relation to their immediate environments. Specifically, the 'Hack-a-Thing' workshops wanted to stimulate processes of creative breakdown and reuse that can unleash the other lives of technologies (Jackson & Kang, 2014). By doing so, these objects become actors in a conversation on what they were in the context of their previous lives and what possible new meanings they can have. This relates to the idea that objects have agency too, making them actors (Latour, 2005). However, "to be accounted for, objects have to enter into accounts" (Latour, 2005 p. 79). Thus, 'Hack-a-Thing' was set up to reimagine the relationships between human actors, non-human actors, the setting of a FabLab and the local youth's own contexts. The paper describes our evaluations together with the participants of what drove them to choose a particular object, how they altered it and the changes the objects brought about in their own contexts. The paper also reflects on the role a FabLab can play in making objects accountable for their future lives and on what this activity of 'making objects accountable' can mean for facilitating infrastructuring processes.

Introduction: FabLab Genk, 'Hack-a-Thing' and infrastructuring processes

According to Gershenfeld (2005), we have entered an era of personal fabrication: we can download or develop digital product descriptions and designs and supply these to the fabricator with the raw materials to process them (Mikhak et al, 2002). In this line of thought, Gershenfeld launched so-called FabLabs: collections of "*commercially available machines and parts linked by software and processes we developed for making things*" (2005, p. 12). A FabLab allows people to develop a prototype of almost any imaginable product. Access to the lab, its equipment and the available knowhow is free (Milanese, 2006), provided that the FabLab user shares his/her designs with others - cf. the principles of 'open source' (Bauwens, 2007; Open source initiative, 2010) - by creating so-called 'Fab-moments': online step-by-step descriptions of the creation process.

Inspired by Gershenfeld's initiative, FabLab Genk - situated in Genk (BE) - was set up. FabLab Genk aims to be more than just a place of infrastructure. This relates to an issue numerous FabLabs struggle with: *"The [Fab]labs were primarily offering infrastructures to students, and [...] relatively passive in reaching out to potential other users"* (Troxler, 2010, p. 9). Therefore, FabLab Genk aims to make local inhabitants partners in a long-term participation process that results in various open objects, systems and services (De Weyer et al., 2013). This process is also referred to as 'infrastructuring', which addresses the challenge of design as being 'ongoing' and a process of 'anticipation' (Björgvinsson, Ehn & Hillgren, 2012; DiSalvo, Clement & Pipek, 2013).

This paper reflects on 'Hack-a-Thing': a series of workshops organized by FabLab Genk (Dreessen et al, 2014). In the next part, we illustrate how the workshops were developed and based on Latour's Actor-Network Theory

(ANT) *(*2005). Next, we describe how the participants evaluated the workshops. In doing so, we also reflect on how a FabLab can make objects accountable for their future lives and on how these workshops can be part of bigger infrastructuring processes.

Objects are actors too: Latour's third source of uncertainty

The 'Hack-a-Thing' workshops specifically stimulated processes of creative breakdown and reuse that could unleash the other lives of technologies: lives that go further than the ones they were designed for. Normally, technologies are designed to function as we want them to. But this also locks "*objects into a world of necessary dependencies that limits the kinds of relations we may imagine with them*" (Jackson & Kang, 2014, p. 9). The 'Hack-a-Thing' workshops are explicitly not limited to repairing objects to their predefined lives. As stated by Jackson and Kang (2014, p. 2): "*Values get built into technology, but* [...] *sometimes alternative values may be introduced through ongoing acts of repurposing and reuse that humans routinely perform vis-à-vis the world of objects around them."* Repurposing - or hacking - allows the objects to become actors in a conversation on what they were in the context of their previous lives and what possible new meanings they can have.

This relates to the idea of Latour (2005) and his ANT: an approach for understanding the social and focused on making visible the diversity of actors - both human and non-human - that constitute social processes (Kamp, 2012). Central to the theory are Latour's five 'sources of uncertainty' in relation to the social. He describes uncertainties on the levels of: (1) the nature of groups, (2) the nature of actions, (3) the nature of objects, (4) the nature of facts, and (5) the study of the social. Concerning the third source of uncertainty, Latour (2005) departs from the idea that the range of actors at work in any consideration of the social has to be increased (Kamp, 2012), since "*anything that does modify a state of affairs by making a difference is an actor*" (Kamp, 2012, p. 71). This means that objects have agency too, making them actors in social processes.

However, Latour states (2005, p. 79) "*to be accounted for, objects have to enter into accounts. If no trace is produced, they offer no information to the observer and will have no visible effect on other agents*". Latour states that objects, by their very nature (particularly relating to their relationships with human actors), quickly shift from being mediators to being intermediaries. This means that objects have the tendency to recede into the background very fast where they remain 'silent'. This makes them no longer actors. Therefore, objects' momentary visibility can be enhanced in order to "*make them talk,* that is, to offer descriptions of themselves, to produce scripts of what they are making other - humans and non-humans - do" (Latour 2005, p. 79). This can be achieved by generating good accounts of them. Latour discusses five ways of doing so: (1) by studying innovations (and controversies), (2) by approaching objects from a distance, (3) by exploring accidents, breakdowns and strikes, (4) by using archives, documents, museum collections, etc. and (5) by using fiction.

Evaluating 'Hack-a-Thing'

To explore the relationship between 'Hack-a-Thing' and Latour's ANT we evaluated the workshops, together with the participants and moderators that took part in the workshop. By doing so, we wanted to find out what drove them to choose for a particular object, how they altered it and the changes the objects brought about in their own contexts.

Context: Hack-a-Thing, the workshop series

'Hack-a-Thing' explored if by introducing (local) youth (16-20 years old) from the city of Genk to the context of a FabLab could allow them to imagine new relationships between themselves and their surrounding objects via, for instance, teaching them new, particular skills (e.g. in hacking) and/or altering their relation to their immediate environments. The workshops were organised as a first means to stimulate long-term participation in FabLab Genk (De Weyer et al., 2013; Dreessen et al., 2014).

The first workshop (July 2012) focused on hacking (i.e. creating new devices from components of old ones, with another function than originally intended) old appliances or used objects (a printer, vacuum cleaner, etc.) that the participants brought with them. The workshop started with an introduction to the machinery available in FabLab Genk and a course in Arduino to teach them the basics. The participants were divided into four groups, guided by a moderator (an expert in programming, designing, making, etc.). The second workshop (September 2012) started with an open call for participation inviting expert programmers, hackers and designers. The youngsters of the first workshop collaborated with these experts in creating a new object or continued working on their project of the first workshop (Dreessen et al., 2014).

The 'Hack-a-Thing' workshops resulted in several interesting outcomes, such as the 'Persistence of Vision Robot' (Figure 1). Using an old, broken 'Roomba' (i.e. the autonomously, automatic vacuum cleaner robot sold by 'iRobot') as a starting point, a group of participants connected its motors to a Motor Drive Shield and an Arduino, allowing them to control the robot's movements. Moreover, the participants attached a row of thirteen small, LED lights to a custom, laser-cut wooden plate, which was placed on top of the robot. When photographed using a long shutter-time, the robot was seen writing 'FabLab Genk' in light. By adjusting the speed and sequence of the blinking LED lights, the robot could write any (short) text fragment and even draw small graphical elements (in loop).

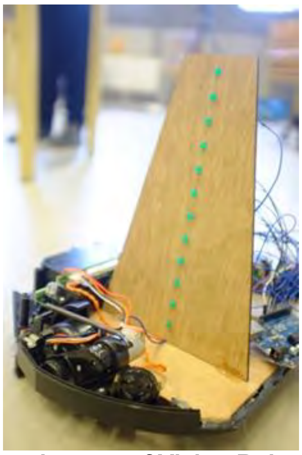

Figure 1. 'Persistence of Vision Robot'.

Another group of participants created a grinder that can burn a large amount of coffee beans (Figure 2). To create this coffee grinder, they hacked into hair dryers and several old vacuum cleaner motors that forced air through a slotted plate and created a vortex that lifted the beans and rotated them. The participants used two temperature sensors to control the heat, in different stages of the burner. Eventually, the coffee grinder was able to burn approximately 400 grams of coffee beans.

Figure 2. The coffee grinder.

Evaluating 'Hack-a-Thing': Methodology

Based upon results of participant observations (DeWalt & DeWalt, 2010) and unstructured interviews with the participants and moderators of 'Hack-a-Thing' (Figure 3), 'thick descriptions' were made (Geertz, 1973). These 'thick descriptions' allowed us to relate our theoretical concepts to what was discussed and conducted during the workshops. In this way, not only the mere facts, but also interpretations of the workshop, the use of technology, results and comments were taken into account. Furthermore, these thick descriptions were analysed from a grounded theory approach to reflect on (1) the role of human and non-human actors in defining future lives of technologies, and (2) what 'making objects accountable' can mean for FabLab Genk. We used Latours' five ways of making objects 'talk' to cluster the results.

Figure 3. Participants and moderators in 'Hack-a-Thing'.

Findings: human and non-human actors in 'Hack-a-Thing'

The observations and interviews showed that all human and non-human actors in 'Hack-a-Thing' have a certain agency. These actors and the interaction between them (i.e. hacking) defined the new future lives of technologies (cf. Jackson & Kang, 2014), as the evaluation of the 'Hack-a-Thing' workshops will show.

First, concerning the non-human actors involved in the workshop, we can state that the objects that were brought to the workshop already determined the end-results of 'Hack-a-Thing' to a great extent. For instance, the Roomba that one of the participants brought already determined partly how the moving 'Persistence of Vision Robot' would look like. The participants indicated that, although they had no idea of what the end-results would be at the beginning of the workshop, they already had ideas of moving robots and therefore immediately recognized the Roomba's potential. Thus, bringing the Roomba to the workshop already defined its new future life to some extent. Other non-human actors that co-defined the new futures lives of the end-results were the machinery and the equipment available in FabLab Genk. In the interviews, the participants indicated that the available equipment helped them to look for other and less obvious ways of dealing with the objects they brought to the workshops.

Second, not only the non-human actors but also the human actors involved in 'Hack-a-Thing' workshops determined these new future lives. Namely, the skills of the participants defined the form the end-results took on. For instance, interviews with the participants showed that the participants that were involved in hacking the objects into the 'Persistence of Vision Robot' all had some expertise in programming software, making the step to include Arduino into the robot rather easy. This also goes for the guidance that the participants received from the moderators in the workshop series. The expertise and background of the moderators in the workshop steered the participants in specific ways, thus influencing the end-results.

Third, we claim that the interaction *between* the human and non-human actors in 'Hack-a-Thing' defines the new future lives of technologies. In this case, the interaction takes on the form of hacking. The broken, old or obsolete objects, chosen and brought by the participants, stimulated and even facilitated the act of hacking, as they were already broken (although with still workable parts) and easy to disassemble. During the observations, we noticed that the participants considered the objects as being a sum of objects (i.e. components that they could use for hacking and creating new objects) instead of one whole object. In this sense, the objects that were brought to the 'Hack-a-Thing' workshops by the participants thus gained agency via the hacking process. Also, objects were given new functions or different goals by connecting them to other objects through hacking. Namely, it was not until the Motor Drive Shield was connected to the Roomba's motor that the 'Persistence of Vision Robot' became able to move. Therefore, the interaction between objects via hacking also influenced the end-result to a great extent.

Finally, we also observed that hacking enabled changes in the relationships between the actors involved in the workshop and their environment. For instance, by partaking in the workshops and sharing his design with others participants, one particular participant that co-created the coffee grinder suddenly became part of an open source community, which - prior to the workshop - was unknown to him.

Findings: making objects accountable

'Hack-a-Thing' also taught us several things concerning the role of FabLab Genk in making objects accountable (Latour, 2005), since various mechanisms for making the objects in 'Hack-a-Thing' 'talk' were incorporated. First, all participants were asked to make their objects accountable through the above-mentioned Fab-moments. Documenting the objects and their creation processes in such a way allows others to create similar objects, work further upon them and/or alter them in new ways. This also changed the agency of these objects: from being end-results in a short-term workshop into starting points to build further upon in a long(er)-term process of reuse, thus facilitating ongoing participation. Second, as 'Hack-a-Thing' was part of the exhibition "The Machine - Designing A New Industrial Revolution", the resulting objects were put on display. Being exhibited - both during the exhibition of "The Machine" as well as later on during the exhibition of "Conflict and Design" - allowed the objects to enter conversations with different actors (e.g. the exhibition visitors) than before (e.g. the participants and moderators engaged in the workshop series).

Both of these ways of making objects talk relate to Latour's idea (2005) of making objects accountable through using archives, documents, and museum collections. Finally, the participants indicated that they made the objects they produced accountable by approaching them from a distance: "*By means of defamiliarization, we tried to reflect upon the objects in a critical way. This provided us with an idea of how the object was made, what it had to do and how it should be hacked in order to become a new object and have certain functionalities"* (Anonymous participant, personal communication, September 16, 2012). This relates to Latour's second way of 'making objects talk' and allows for the participants to form new relationships with the objects they encountered in the workshops.

In this sense, we can state that 'Hack-a-Thing' illustrated that making objects accountable can facilitate (1) long-term processes of on-going participation, and (2) new relationships between actors and their (local) environment. Within the context of FabLab Genk, particularly the documentation of objects through 'Fab-moments' or exhibitions is constantly stimulated and through this numerous objects have already been shared, rebuild and adapted in new ways.

Conclusions

We approached the 'Hack-a-Thing' workshops series as a social process, as studied by Latour (2005). In this process, both human and non-human actors play a role as well as the interaction between them. In the specific case of Hack-a-Thing, interaction took on the form of the act of hacking. We showed that this network of actors altogether defined the new future lives of technologies (cf. Jackson & Kang, 2014). In this way, new user-object relationships are stimulated. Furthermore, the Hack-a-Thing workshops are a way to extend the object's lifetime (the predefined but also the other lives). This paper also illustrated that making these objects accountable allows for the facilitation of long-term and on-going participation, a specific aim of FabLab Genk.

The role of objects as non-human actors and their interaction with other (non-human or human) actors remains underexposed, due to them remaining unaccountable. We refer not only to workshop formats but also in everyday life (e.g. in our working environment or household): what is the impact of objects and how do they co-determine the shaping of social processes? By doing so, the ideas we explored in the Hack-a-Thing can be taken out of a workshop context and up scaled to everyday life. Therefore, 'objects are actors too', meaning that future research should focus on further exploring the role of the objects, as well as on making these objects accountable. After all, objects can be catalysts for different relations with the (local) environment.

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Designing for fast and slow circular fashion systems: exploring strategies for multiple and extended product cycles

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Keywords: lifecycle design; practice-based; fast and slow fashion; disposable and durable materials.

Abstract: This paper reviews work conducted by practiced-based textile design researchers based at the University of the Arts London (UAL) who were part of the multi-disciplinary, Swedish-based Mistra Future Fashion research consortium between June 2011 – May 2015. The objective of the consortium was to research opportunities to advance a more sustainable, yet still profitable, fashion industry. The final stage of the project involved developing practice-based approaches through physical exhibition prototypes, which formed the basis of the project's online exhibition, The Textile Toolbox (Earley & Goldsworthy, 2014).

Here we discuss two of these design prototypes which both explored 'designing for cyclability' as a proactive approach to improving the retention of material value within 'circular fashion systems'. Designing in order to enable fully joined up cycles of material use is the ultimate aim for both approaches, but this 'speed' of cycle creates very different challenges on which to make informed and appropriate design choices.

The two approaches are deliberately extreme opposites, with 'short-life' closed-loop garments explored as complementary to 'long-life' user engagement strategies. Both can ultimately be argued to have an 'extending' affect on materials in the value-chain; one by keeping products in use over multiple cycles in perpetuity, the other by extending the single use cycle of a product over time. By exploring this polarisation of 'speeds and needs' we aim to gain insights into creating an effective circular materials economy, which acknowledges the complex nature of our current and emerging fashion system.

Introduction

Environmental impacts from waste in the fashion and textile industry continues to grow at an ever more rapid pace. 'Between 2.5 and 2.7 million tonnes of textiles are consumed annually in the UK. Of this, between 1.1 and 1.4 million tonnes are clothing' (WRAP, 2013).
Looking ahead to the potential of new materials and services, how can textile designers meet the challenge of fast fashion in more appropriate ways?

Recently there has been a rise of projects that encourage and support textile and fashion designers in considering their responsibilities as creators of sustainable products and systems (e.g. Fashion Futures 2025), but they have been struggling to find a way to both comprehend the complexity of the challenges and to know how to go about tackling them in a scalable and economically viable way.

'Traditional UK markets for recycled textiles are declining. Market development funding, including innovation, demonstration, standards and/or capital funding for selected new markets will help to stabilise this decline and also create new markets.' (Morley et al, 2009)

This paper reviews the work conducted by a team of University of the Arts London (UAL) practiced-based textile design researchers who were part of the multi-disciplinary, Swedish-based Mistra Future Fashion research consortium between June 2011 – May 2015.

Textile toolbox

The objective of the consortium was to research opportunities to advance a more sustainable, yet still profitable, fashion industry. In the first half of the period the research team and external collaborators used 'The TEN' (Earley &

Politowicz, 2010) to review current design decisions and best practice for fashion in Sweden and globally. The TEN are design decisions that range from the material, to shape and form, fit and finish, processes and technology; to systems and services, consumer centred concepts; and finally design activism.

Informed by this research mapping, the team then explored new design models by testing The TEN with industry stakeholders (H&M and SME's at the Sustainable Fashion Academy); and subsequently by using their own particular practice-based approaches. The resulting models – physical exhibition prototypes – formed the basis of the project's online exhibition, The Textile Toolbox (Earley & Goldsworthy, 2014).

As the models were developed the research team found that almost all the ten models – with the exception of one, which addressed democratic design tools for the user – addressed designing for cyclability, amongst a range of other strategies. These new models included those which were at once proactive or reactive; using natural or manmade materials; suggesting closed or connected systems or loops; and also fast or slow products (Goldsworthy, 2013).

In this paper we will discuss the interplay between 'speed' and 'approach' for cyclability, using two prototypes from the project as case studies for consideration. Designing in order to enable fully joined up cycles of material use is the ultimate aim, but the 'speed' of the cycle also needs to be considered in order to make informed and appropriate design choices.

Designing to enable material flows within current (fast) industry systems is here explored through ASAP (Goldsworthy & Politowicz, 2014). Paper-like clothing that has been designed not to be washed, and instead composted or recycled after a short user life. Designing to enable extended product life through consumer engagement is here explored through Fast Refashion – a polyester shirt overprinted by the user at home (Earley, 2013).

Both of these approaches, although seemingly opposed in approach, can ultimately be argued to have an 'extending' affect on materials in the value-chain. One by keeping products in use over multiple cycles in perpetuity, the other by extending the single use cycle of a product over time.

'…value creation potential stems from keeping products, components, and materials in use longer within the circular economy. This can be done by either going through more consecutive cycles or by spending more time within a cycle. This prolongation of usage will substitute virgin material inflows to counter the dissipation of material out of the economy (which, assuming constant demand and given the second law of thermodynamics, i.e., 'matter is decaying towards entropy', will eventually happen).' (Ellen MacArthur Foundation, 2013)

This paper proposes that there is a very different set of material and design approaches needed for short-life (fast fashion) products, designed for efficient recovery of material resources when compared to long-life (suitable for extended life services) garments, which needs to be designed for durability.

This deliberate polarisation of the range of clothing available through design conforms to the 'Well Curve' (n/d) has two spikes and is a reverse of the 'Bell Curve' theory in which society's benefits gravitate to the centre. Taking what is the 'best' in the system and applying the idea to the extreme could match behaviour and become a sustainable solution.

There is very little practice-based research in the fashion field that refers to these opposing product speeds or rhythms. 5Ways (Earley & Fletcher, 2003) tested design approaches based on needs, with the 'Updatable T-Shirt' experiencing an extended life through a series of interventions by the consumer.

'Fashion clothes capture a moment in time and are as quickly forgotten. But what if that moment was not one but many moments… a process of transformation?' (Earley & Fletcher, 2003)

In 2007 Fletcher and Tham considered the idea of garment 'archetypes' and scenarios in 'Lifetimes'; yet little practice-based work since has expanded upon this notions.

Short-life fashion

Designing for Material Recovery

This concept is based around the idea of designing for multiple-short cycles that can be recollected and transformed for future use as new materials. Biodegradability, mono-materiality and low-energy production are key attributes.

'… the fastest flowing products… need to be fed into a recovery stream as soon as they have finished being used. [But] our lack of understanding in the design industry around effective material recoverability can create more waste through misinformation, which can contaminate valuable recovered materials… The design brief must be strongly influenced by the end of life of the product.' (RSA, 2013)

This approach may radically reduce impacts associated with laundry and material production. Enlightened design needs to be applied to the fast fashion reality: the social, ecological and economic impacts. Connecting existing (albeit unrelated) industries – such as fibre, fashion and waste recovery, is a logical way to process raw material and recover existing material.

In order for this project to achieve maximum impact, new and agile production technologies need to be explored and the system for recollection and recycling also need to be designed as part of the vision.

This concept is an extreme opposite, but complementary to 'heritage quality' and 'long-life' strategies, and suggests that new products should be 'proactively' designed with the conscious goal of enabling material value retained through future material cycles. To do this a designer must first identify a specific end of life route for which to design towards.

(A.S.A.P.) Fashion Forward Paper Clothing

This approach responds to the prevailing 'disposable' culture in fashion and asks if it could be transformed by the development of inexpensive, bio-based 'recoverable' garments with sustainable production and disposal credentials. It also aims to eliminate the 'consumer washing' phase and therefore remove this part of the large carbon footprint.
By connecting compelling strategies for economic growth with sustainable, fast track business models, raw materials are developed to offer alternative, renewable qualities as a complement to the resilience and durability of an existing, classic, wardrobe.

Figure 1. ASAP's paper-fabric garment project, 2013-14.

For this exhibit, UAL researchers Politowicz and Goldsworthy collaborated with materials scientist Granberg (Innventia), industry consultant MacLennan (East Central Studios) and fashion designer David Telfer, to produce a collection of material samples and a jacket, made from a wearable, non-woven cellulose based material (Figure 1).

Through the collaboration between designers and scientists, a new material was developed which responded to the multiple requirements set by the designers of softness and drape, coupled with strength and stretch. To achieve this the material scientists focused on a blend of wood fibres and PLA fibres, which can be produced using current mass production and recycling systems from the paper industry. By varying the fibre composition and weight, different tactile and functional qualities could be achieved.

A further stage of processing was developed in the finishing of the materials which was used to impart qualities not possible through fibre composition and construction alone. One of the most successful finishes applied was that of micro-pleating, a method for creating mechanical stretch in an otherwise non-stretch substrate. This imparted textile-like qualities into an otherwise paper-like material thus improving its suitability for garment use.

Laser finishing (Goldsworthy, 2012) was another successful finishing technique applied as a way to create different properties and surface qualities including glossing, laminating and print-effects and which could be used to transform the material post-production according to the particular requirements of each design (Figure 2). It was also used as a way to weld the seams on the final garment, thus negating the need for stitching which reduces the strength of nonwoven materials due to its 'perforating' effect.

Figure 2. 'Laser finished' monomaterial samples, 2008-11.

During the initial stages of the material development user testing was carried out at Innventia, Sweden, in order to assess the viability of the materials in terms of consumer acceptance. These user-based perception studies were carried out by Innventia and showed that the paper materials developed stood up well against more traditional fabric qualities in terms of handle and tactility.

The effects of this kind of short-life, closed-loop technical approach are limited to suitability for certain garment archetypes within the current market, but the researchers are interested to continue development in conjunction with industry input to test the viability of the approach further with appropriate market segments.

Could this concept, coupled with the following long-life approach, work together in order to provide extended material value solutions for a large part of our current fashion landscape?

Long-Life Fashion

Designing to Prolong Material Use

This concept is based around the idea of designing for extended use single-cycles whereby existing products can be kept in service over a longer-life. Durability, adaptability and personal connection are key attributes.

This approach may radically reduce impacts associated with material production and manufacture. Enlightened design needs to be applied to increasing demand for more durable fashion garments. Here the opportunities lie in connecting retailers and designers with consumers, and with garments designed for new business models - where clothes are recirculated to users as many times as possible to ensure that the greatest possible value is gained from a given garment over its lifetime.

This concept suits the new and emerging business models around: services for extended life of garments (e.g. Barbour, n/d); collaborative consumption; own brand resale (e.g. Filippa K, n/d); luxury second hand; leasing and many other models. By designing with these specific scenarios in mind, products can be designed for longevity and transformation; by both the designer and the user.

Figure 3. 'Updateable T-Shirt'. Source: 5Ways, 2003.

(Fast ReFashion) Designing Fashion Services

The idea that consumers can be more creatively engaged in the transformation process of a product in a single cycle was tested as part of 5Ways (Figure 3) where the researchers asked six graduates to transform an organic cotton t-shirt using a brief that arrived by post each month. The skilled textile graduates completing the tasks reported feeling 'anxious' about making the changes; which raised the question of what additional support *untrained* consumers might need.

Fast ReFashion (FrF) approach is to transform the industry through designing services, rather than the creation and sale of new products (Figure 4). This outcome of Earley's Top 100 work (2014) facilitates users to create a monomaterial refashioned garment for themselves, using readily available tools like irons, paper and dry foods.

Figure 4. Black Hack, 2012–2014 & Fractal Shirt, 2013.

The FrF model references the speed of high street trends, but draws users away from the shops and back to their wardrobes for the garment that will begin the material, and perhaps the personal, transformation. The service offers consumers support through events, demonstration films and downloadable instruction kits.

'Previous studies have shown that the most common reasons for premature disposal of clothing are fit, fashion change, boredom, and damaged/worn out goods, all of which could be addressed through innovative PSS (Product System Service) models designed to reduce material throughput by eliminating the need for disposal while raising the customer's satisfaction with the product.' (Niinimäki, 2013, p. 105)

The approach has been tested with stakeholders throughout phase 1 of the Mistra project: at the Black Hack 10 researchers were invited to design and execute an overprint for a polyester garment using the heat press; in the next iteration Black Hack Chat (EAD10 conference, Gothenburg, 2013) domestic irons were used by conference participants working on tabletops covered with bed sheets.

Although technically simple, the workshops revealed that without aesthetic guidance from the resources provided, the results were often too naïve to enable users to feel that they had added value and created something wearable. The users enjoyed the company and discourse with other users and the support and guidance provided by the 'experts' (Earley & Ballie, in von Busch *et al*, 2014).
The effects of this kind of extended life approach would always be limited in terms of volume, but the researchers are keen to understand if this kind of hands-on experience would lead the consumer into behaviour change around fashion consumption. Textile Toolbox is currently enabling the FrF model to be explored further by providing downloadable resource sheets, PDFs that give the user information to create their own FrF garments and events. Feedback from this interaction will be used to refine this approach in phase 2 of the Mistra research.

Conclusion

Working with multiple partners and collaborators, we are planning to develop these two speeds further during the next phase of the Mistra Research project (2015 – 2019); and to produce a revised set of design guidelines that help designers work towards a circular fashion system and the consumers who may populate it.

Context is everything. We need to be very clear which segment of the fashion industry we are designing for and also which specific garment archetype. Whilst some strategies may be more relevant for the mass market and high street fashion (short-life), others will be focused on more niche, SME brands and even reach beyond industry to the user (long-life) (Figure 5).

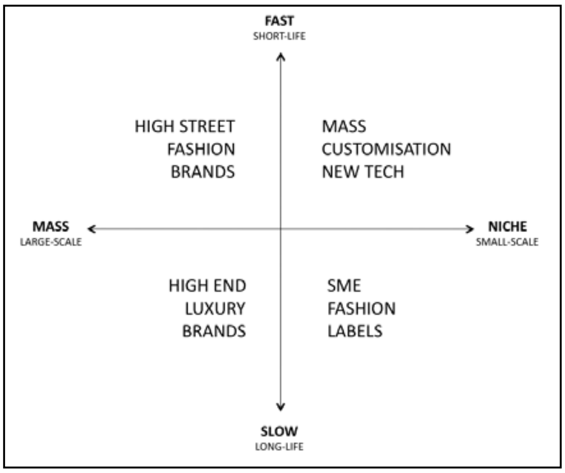

Figure 5. Fast versus slow; mass versus niche – the landscape of potential for extending the life of fashion products. Source: Goldsworthy, 2014.

However, there is also the possibility that luxury brands may find long life 'service strategies' open up new markets; shifting users away from buying items from the brand for the signature that has transitory trend value but more permanent material implications.

Likewise, in many ways the short life products could be found to have new meaning implications for the way in which we view long life. In short, by keeping paper (-like) products in a wide range of perpetual single cycles we are in fact achieving long life with these products.

Both the short and long life approaches come with a variety of potential social benefits. The context for each prototype will be developed further during the next phase of the Mistra project (2015 - 2019). These design approaches will work in tandem with materials research and measurement tools (LCA and user-perception studies) to gain a new discourse and level of understanding around our fashion material 'speeds and needs.'

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The relationship between ideas about cleanliness and actions that affect product longevity

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Abstract: As Mary Douglas famously put it, 'where there is dirt there is system' (1991 (1966): 35). She was concerned particularly with the cultural systems that determine the ideas about dirt that motivate and constrain people's actions with material objects. This paper assumes that such motivations and constraints may affect consumers' willingness to keep or to dispose of their possessions, and therefore have an impact on product longevity. It reports on ongoing empirical research using product analysis, ethnographic interviews, a questionnaire and student design work into the possibility of increasing the longevity of vacuum cleaners by design interventions.

Because its object of study is a cleaning product used in everyday cleaning practices, the research naturally connects with Douglas' ideas as well as more recent work such as Dant 2003 that focuses on how people deal practically with the materiality of dirt, not determined by cultural categories. This paper builds on Vaussard et al.'s (2014) classification of individuals by their degree of concern for keeping their house clean, into 'Spartan', 'Minimalistic', 'Caring' and 'Committed' cleaners and their implications for vacuum cleaner replacement. Introducing a short history of concern about dirt since germ theory, it considers whether the desire for a more up to date/ efficient/ powerful/ good looking/ clean/ shiny machine may accelerate replacement. It finally considers whether a design that 'ages gracefully' might have a longer life-span, either as a personal possession or as part of a service system.

Introduction

This paper is about dirt, which is not a simple matter. Dirt is both 'stuff' and value. It is physical stuff which has certain properties, some of which may directly disgust us, but it is also stuff we may not like because of what we think about it. The paper explores some of this complexity through a body of research about vacuum cleaners co-funded by Defra and WRAP. Through questionnaire, interview, focus groups and consumer workshops, this research has explored the potential to reduce the throughput of embodied energy that results from the consumption of vacuum cleaners by increasing their life-span. It has used a human centered approach (Giacomin 2014) to work out how design interventions could result in people keeping their vacuum cleaners for longer. Among the research questions were whether and how the physical ageing of vacuum cleaners may stimulate their replacement. The research has shown that the particular ways vacuum cleaners themselves get dirty, damaged and marked shows that 'dirt' both as a cultural category and as physical matter is implicated in their replacement.

If dirt is implicated in replacement, it is one of a set of powerful pressures on consumers' decisions to replace their vacuum cleaner. These result in a gap between the machines actual lifespan and their possible lifespan. From 2009 to 2012, 44% of UK households bought a vacuum, making it the second most frequently bought domestic appliance (Mintel 2013). Half of the machines purchased in 2012 were replacing an existing product under 5 years old, but they are expected to last for longer (WRAP 2013), from 5 to 7 years (Brook Lyndhurst, 2011).

The paper first considers some ways of thinking about dirt, from social science and design history, then reviews some of the results from the research. This indicates that dirt is certainly an operative cultural category for all types of users, as well as having physical properties that must be dealt with. The differences between users' approaches to cleaning are important in their decisions to replace a vacuum cleaner as is the nature of the dirt involved, and shared ideas about how to deal with it.

Ideas about dirt in practice

In the practice of home cleaning dirt is a focus of complex overlapping and sometimes contradictory concerns that have both material and non-material components. For example, the presence of dirt may be understood as a danger to health, as well as a mark of social incompetence and low status. The dust we can vacuum up may stimulate a feeling of duty to eradicate it as well as being real stuff that sticks to skin and to the surfaces of objects, clouds the air and gets up the nose.

This reflects the complexity present in theoretical approaches to dirt. It can seem that the physical matter in question is less important than the social/ cultural system that marks it out as dangerous. This very influential position developed by Mary Douglas in her Purity and Danger (1991 (1966)) was subjected to a critique more recently by theorists concerned to put the 'material' back into her account of material pollution. Dant and Bowles' 2003 account of mechanics dealing with the dirt they encounter every day represents a newer approach to dirt that has emerged from the so-called 'material turn' in the humanities and social sciences (see for instance Pierides and Woodman 2012).

The discovery of the relationship between bacteria and disease in the C19 by Pasteur and others (Worboys 2000), led by the end of that century to a strong association between dust and disease. The physicist John Tyndall first proposed this association (1870). Finding a way to produce a container full of dust-free air to experiment with light, he noticed he had also produced an environment in which organic matter did not rot. This association between dust and disease brought new pressures to bear on the duties involved in dealing with dirt in households and in cities. Alongside its effect on physical hygiene, it changed what we think about dirt and as a result affected what we think we should do about it. The design of cities to provide supplies of uncontaminated water was one outcome. Efforts by the 'sanitary reform' movement to control a wide range of health hazards including 'fly-tips, abattoirs and industrial hazards' were another (Worboys 2000, p. 26), alongside the design of systems to deal with waste and keep streets clean (Rogers 2005).

Beyond these practical steps, the connection between dirt and disease produced a strong moral frame for action. As Forty describes (1986, p. 159ff), mixed with class prejudice this soon exceeded its origin in the scientific understanding of disease transmission and all dirt came to be classed as morally damning. As he puts it (ibid, p. 168), '…hygienists turned increasingly to methods that exploited guilt. However, before guilt could be brought into play, cleanliness had to be transformed from a physical problem to a moral one.' Consequently, hygiene campaigners became focused on the individual conduct that could prevent dirty bodies and dirty houses.

The aspect of Forty's historical narrative that is most relevant here is the observation that health campaigns were relatively ineffective in characterizing dirt as the origin of ill-health compared to consumer product design and advertising. By the middle third of the twentieth century, achieving hygiene by battling dirt underlay campaigns to sell products ranging from domestic and office furniture to bathrooms. And of course, since they were invented to directly combat disease-carrying dust, vacuum cleaners are a prime example of this proselytizing through design.

Forty identifies the ways designers of furniture and architecture responded to the growing association between dirt and disease – these included furniture that had no carving or mouldings, as well as a preference for fused, hard materials that would not absorb muck. He suggests that the modernist preference for chrome and glass derived not only from their 'association with machines', but also because they could be kept looking clean. Progressive modernist designs therefore intertwined the abstract rhetoric of hygiene with the actuality of performance – these were designs that both looked clean and were clean. As he puts it:

"The history of the vacuum cleaner is a good example of the commercial applications of the phobia against dirt, and of the way appearance and styling were affected by the imagery of hygiene" (ibid, p. 174).

This potent combination of moral and material became by the early C20 something that individuals displayed through their possessions and continues to be. Just as early in the twentieth century, the possession of a bathroom indicated a 'good' family, owning a vacuum cleaner meant an ordered hygienic household – measuring up to the moral imperative to battle dirt as a crucial aspect of responsible housekeeping.

Contemporary dirt

Forty infers these connections between designs and the moral imperative of hygiene from the social milieu in which the designs appeared and reads them out of the form of the designs themselves. The research on which this paper draws has shown the progressive futurism that Forty saw in the design of vacuum cleaners, and the theme of social 'face' that he associates with the social role of vacuum cleaners, still to be at work. However, its direct engagement with consumers means it is able to see these themes at a finer level of granularity and to bring out their relationship to product longevity.
As one of the focus group participants said of the dust that his vacuum cleaner collects, 'you don't know what it's doing to you'. He was not alone in expressing his concern about the effects of the special sort of dirt that we vacuum up. Taking a cue from Dant's focus on the material properties of the dirt, against the cultural systems that define it, it is worth considering some of the special qualities of the dirt that swirls round the canister of a bagless vacuum. Dant refers to the Sartre's description of slimy substances in Being and Nothingness (1984) to focus on bodily responses to dirt. Whereas Dant's concern is for dirt that is actually slimy, dust is not; however, it is made of particles that are small enough to work together as a fluid, losing their identity as discrete identifiable elements. Like slimy substances dust attaches itself to the skin and to surfaces and stays there – it won't run off. But it doesn't 'pull' like slimy stuff; it isn't tacky. Indeed, it is similar to some dry substances made of tiny particles that may be pleasant to touch, like dry sand or flour, but unlike those substances, we don't really know what dust is made of. The nearer things come to the mouth, the more salient they are to us, and the keener is our evaluation of them (Fisher 2004). Dust sticks to us, it flies about and we may breathe it in, not sure it doesn't carry pathogens or be otherwise harmful.1

Alongside the dirt accumulating in the vacuum that we have to deal with when emptying the canister, changing the bag, cleaning filters, un-blocking the tubes or removing trapped hair or other items, vacuum cleaners themselves get dirty as they are used – dust sticks to their plastic surfaces. This loss of physical 'gloss' with age is only partly responsible for the object looking used. Styling obsolescence also plays a part in this and Forty notes that as early as the 1930s, vacuum cleaner manufacturers were following the lead of the automobile industry and introducing changes to the appearance of their designs to stimulate sales by using appropriately progressive, futuristic motifs. The constant arrival of new models means a vacuum cleaner is likely to begin to look dated at the same time as it becomes dirty – losing its physical 'gloss' and its aesthetic appeal. Following Douglas it is possible to class this aesthetic ageing, alongside the moral frame described above and the physical contamination involved in vacuuming, as different components of 'dirtying':

"With us, pollution is a matter of aesthetics, hygiene or etiquette, which only becomes grave in so far as it may create social embarrassment" (1991, p. 73).

Types of dirt, types of cleaners and disposal

The practice of vacuum cleaning is structured round the ideas discussed above, which play out through the orientations that individuals have to the activity of cleaning. Vaussard et al. (2014) identified four 'types' of cleaner, for whom dirt and cleaning have different level of salience, and who clean their houses more or less frequently. These types, and their frequency in the population studied here, are as follows:

1. Spartan cleaners (12%)
2. Minimal cleaners (34%)
3. Caring cleaners (40%)
4. Committed cleaners (10%).

[1] We might enjoy manipulating flour in cooking, but be less able to if we are not sure it doesn't contain weevils. We might enjoy the feeling of sand on our skin at the beach less if we think too hard about the people who walk their dogs there. These thoughts are the equivalent of the cultural knowledge that Dant identifies as overlaying the phenomenal presence of dust and dirt.

The four types differ in the importance they place on cleaning their home – they consequently have different relationships to the moral frame outlined above. So it should be possible to see within the orientation of these types to cleaning practices, and vacuum cleaners, more and less positive views of that moral frame.

Our empirical work revealed that there are other matters that affect individuals' relationship to vacuuming, which are closer to the materials involved than to the moral systems and seem therefore more likely to be explained by Dant's (and Douglas') reading of Sartre's passage on sliminess and stickiness.

Some participants, for instance, seemed to reject the moral dimension of a concern for cleaning. These members of the 'spartan' cleaner type seemed to be at a particular (early) life stage and to take an entirely instrumental approach to their vacuum cleaner, its use and its replacement. For this group, the machine is simply a servant, a piece of necessary equipment that does not deserve much care - they are not concerned for its appearance. In contrast, for individuals at the other end of the spectrum in the 'committed' group, the appearance of the cleaner, and its visibility, are very important. A case in point was a family vacuuming several times a day, storing the machine in sight in the hallway. The rationale was that their child-minding business required them to demonstrate the cleanliness of their home and their commitment to it - the moral dimension of cleaning was to the fore as part of their public face.

However, there was little evidence for a desire to get a new vacuum cleaner because the old one no longer looks good, though this varies with cleaner type. Some 'committed' cleaners said their scuffed current machine was looking 'used' and one expressed a desire for something 'new and shiny'.

'Spartans' notice dirt but do little about it - cleaning is not of great importance to them and they may vacuum only once every two months. 'Minimalists' feel a little uncomfortable noticing dirt around the house and have some motivation to clean but it is not a priority and only done when they have time. 'Carers' want a clean and nice-looking home to demonstrate to others they have a well-working, ordered, "home ecosystem" that is a healthy environment for their families. 'Committed' cleaners clean almost obsessively, spending considerable time tidying up, and doing cleaning tasks to a high standard is a priority for them.

The physical characteristics of the dirt they are dealing with is a constant for all these cleaner types. Some reported having allergies, giving them a particular relationship to the wafting dirt that the vacuum cleaner is designed to control. But when this un-differentiated matter flies around when emptying bags or canisters it may get up your nose and make you sneeze, even if it doesn't make you ill. The visibility of dirt was simultaneously a positive and a negative for participants. Some reported a sense of satisfaction and achievement at being able to see the dirt collected in a canister machine. On the other hand, whether allergy sufferers or not, participants reported taking care to avoid contact with dirt when emptying the canister carefully outdoors.

As the look of a machine deteriorates with use, it tends to be stored out of sight suggesting the mild disgust engendered by dirt may have a role in disposal decisions. Some participants said the look of the vacuum cleaner determined their willingness to keep it 'in sight' - a practical response to lack of space and need for convenience aligns with the degraded aesthetics of the machine. Several participants who had more than one vacuum cleaner kept a less favoured one out of sight, in a cupboard or shed.

So the hygienic design rhetoric of the machines that Forty identified remains significant, and may have consequences for their longevity, with overlapping aspects in current vacuum cleaner designs. Convoluted moulded plastic details characterize the design language used to signify technical advancement, which harbour dirt and invite rapid physical deterioration, becoming irrevocably dirty and broken. On inspection, used vacuum cleaners were often covered with a fine dust through static attraction and the materials and design features meant that any damage they had sustained would be impossible to rectify without replacing large plastic components.
This design language, drawing from sci-fi and computer games will become obsolete with shifts in fashion and popular culture. However,

this inevitable dating did not seem to be a problem to most participants, who were happy to have vacuum cleaners that cost little to replace once they no longer work or are unfit to be seen in the house.
Clearly, a number of factors in which dirtiness may be implicated determine the point at which a vacuum cleaner is discarded. One is the disposition of the owner towards 'newness'. All three of Campbell's (1992) types of consumer motivations to acquire new possessions seem to be present in participants' motivations to replace their vacuum cleaners, and their choice of machine. 2 For example, a 'pristinian' consumer may be less inclined to buy a bagless vacuum cleaner because a conflict of attraction and repulsion is built into this design.

The empirical work suggests that the sense of mild disgust engendered by the dirt that vacuum cleaners capture may have a role in disposal decisions. A machine that is both dirty on the outside and reveals the dirt captured on its insides may need relatively minor mechanical problems or damage to the exterior to prompt disposal.

Discussion and conclusion

The work reported here indicates that the moral framework that developed in the C19 round dirt in general, and dust in particular continues to influence the practice of vacuum cleaning, including decisions about when to replace machines, and therefore, their longevity. The ways in which the machine ages, its styling, the ability to clean it, the nature of its materials are the consequence of design decisions, so may be altered.

The students' involvement in the research proposed forms and materials to promote 'ageing gracefully', prolonging the owner's attachment to the machine, in the context of both individual ownership and service systems. In both contexts, while participants agreed that a durable aesthetic and more 'honorific' materials (Veblen, 1994 (1899)) were attractive, they expressed doubt over the actual durability of materials such as wood or leather, even though plastics are demonstrably fragile. They also indicated that a large component of their trust in a machine derives from its brand identity, which would be absent in a leasing or service system scheme.

Given that brand identities are among the most pervasive and perhaps powerful of the cultural influences on contemporary consumers, it is appropriate to note their significance in this context. As Douglas puts it, culture 'mediates the experience of individuals' (ibid, p. 38) and in particular, their direct personal experience of the substances that it classifies as dirt. Nonetheless, these substances have agency too and dealing with them requires that we develop habits and routines that can cope with their capacity to directly disgust us.

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Understanding the caring practices of users

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Keywords: caring; maintenance; user behaviour; design.

Abstract: This paper explores how people extend and preserve the life of specific objects and domestic spaces through 'caring', drawing on early findings from an empirical study conducted by an interdisciplinary team of researchers at Sheffield Hallam University. Researchers from across the design disciplines of fashion, product and interiors explore the attitudes of users towards care routines by profiling and comparing the specific practices, customs and rituals that are adopted in the care and maintenance of products and domestic spaces in regular use.

During the 20th century the cultural and economic value of products dramatically changed as the availability and affordability of mass-produced, low cost goods increased in the marketplace (Walker, 2006). As a consequence, the emphasis on product care and maintenance has become less important, and is fostering a "careless" society in which a growing lack of skill, knowledge, and motivation means that users do not routinely engage in the appropriate care practices that are known to help extend the life or use of particular objects and spaces. Although in general terms consumer products have come to be considered disposable, it is argued that through 'good' design there is an opportunity to establish an emotional bond or attachment between user and product that together with associated practices of care can help sustain and extend product lifetimes (Chapman, 2005; Walker, 2006; Schifferstein & Zwartkruis-Pelgrim, 2008). However, while the designer may be able to enhance the relationship between user and product, this paper highlights a range of unpredictable care practices that exist amongst consumers, which can affect these intentions. Motivated by a desire and the perceived need to encourage users to engage more with care and maintenance routines as a means to preserving the life of products and environments, this research reveals user-centred insights that may help designers to support and encourage better maintenance and 'care' practices.

Introduction

It is well known that the life of a product can be strongly affected by the treatment it receives during use (Cox et al., 2013). Undertaking simple repair procedures, using appropriate cleaning products and processes, and testing and maintaining working parts and components etc., are steps that can be undertaken by users to preserve the life of products and domestic spaces. Although regularly used products and spaces "…depend upon our care and attention in order to survive" (Chapman, 2005, p.72), for many, contemporary life is demanding, and the time, dedication and attention that may be needed to care for products and domestic spaces, is limited.

It is important to recognise that product lifetimes vary enormously. While some items are developed to be disposable, for example medical supplies and paper plates are discarded for reasons of hygiene and safety (Walker, 2006), other products are developed for longer lifetimes that operate within a variety of market needs and consumer expectations. However, regardless of the perceived lifetime of a product, factors considered during the design process can potentially lengthen or shorten its life during use. For example during design and development a product lifetime may be reduced because of the decision to use inferior materials and cheaper manufacturing processes for construction. Or more perceptually, product aesthetics governed by seasonal trends, can sooner or later become outdated (Walker, 2006). For the user these design/development/manufacturing decisions can complicate their understanding of actual/expected product lifetimes, and challenge preconceived ideas around the correlation between brand and price as an indicator of a long lasting or durable product.

However, while users may find it difficult to establish the actual lifetime of a product, as Cox et al., (2013) observed, people are generally satisfied if a product lasts without breaking down for as long as it is needed, but they do not expect the item to last longer than this. This means that the value that is placed on the durability, and the functionality of a product can be different. While functionality plays a critical role during use, durability (to extend the life of the product beyond expected time periods) may prove to be a less important consideration.

While these observations point to a complex picture of needs and beliefs, it could be argued that to meet even minimal expectations of use some form of care by the consumer is required to ensure a product or space remains functional. Norman argues that products should be developed for pleasure, for use and for meaning, and that to potentially improve our engagement with products during use, a product should embody four components; "function, understandability, usability, and physical feel" (2004, p.70). While this is a useful framework, it places the emphasis of responsibility on the designer to develop a product that meets these intentions. However, an alternative proposition would be that responsibility is shared between producer and user. Users, it could be argued, have a duty of care to engage with appropriate care and maintenance practices that are known to help retain the functionality of products and domestic spaces throughout their lifecycle. (Gwilt, 2014). This research begins to investigate if care practices are a regular feature of peoples' lives, and if not why, and how can they be re-engaged?

Background

Maintaining the life of products was an integral part of the everyday up until World War II. People routinely engaged in practices recommended to protect and prolong the life of new products, and advice manuals, whilst not always followed, provided information that became commonplace in daily life (Strasser, 1999). Strasser argues that while Americans engaged in a consumerist culture in the nineteenth and early twentieth century, "…they mended, reused, saved and made do" due in part to frugal living and an appreciation for the material value of goods (1999, p.22). However, these perspectives were not seen as "…a conscious virtue or as self-denial but as a way of life", that was instead led by a recognition for usefulness. (Strasser, 1999, p.28).

In the latter part of the twentieth century the need for durability was superseded by a desire for convenience and affordability that enabled people to buy products at ease; for leisure, and disposability. Recent technological developments in computing, mobile phones, entertainment devices and so on have only affirmed this custom. Consumers are promised goods that provide 'ease of use', are 'fashionable' and 'maintenance-free', that satisfy human desires rather than needs (Whiteley, 1993). In the predominant model of contemporary consumption it appears that users are not overly interested in extending the life of products, and in particular items purchased for their fashionability are often treated with little care during use because there is an expectation that they will be replaced before they become damaged or broken (Cox et.al., 2013). Furthermore, Cox et al. (2013). suggest that this means simple, preventative care practices, such as repairing shoes or using protective coverings are comparatively rare. Shove (2003) argues that there is a "…niggling tension between the production, appropriation and maintenance of standardized and localized interpretations of normal practice", and it is this tension between the generic and the customizable that has, and continues to, plague our modern consumerist society. As improved product accessibility and affordability has made the disposability of products a standard practice, then it becomes harder to argue for the 'localized' care practices needed to preserve and maintain existing products and domestic spaces. People do typically keep some products for longer if they are considered to provide a 'functional service' (Cox et al., 2013) but is functionality the only reason for employing care practices?

Perspectives on care

While a 'care perspective or care thinking' is commonly connected to Social Policy, Health and Social Care (Barnes, 2012) there is little formal interpretation of this term in respect to the practice of design or how we think about designing. Design anthropologist, Elizabeth Dori Tunstall (2014) argues that while empathy may be encouraged through design as a way to challenge apathy, the value of 'caring' involves action. Acknowledging advocates of empathy such as Tim Brown at IDEO (2013), who suggest that empathy can enable designers to understand the experiences of others, Tunstall considers that empathy alone does not automatically involve the more positive act of caring.

Engaging with 'care thinking' may in addition lead designers to consider how users can be motivated to participate with care practices during use. Although Norman proposes that affection for a product is earned through the discrete interactions that are displayed between product and user, "…an object's special characteristics makes it a daily part of our lives, when it deepens our satisfaction, whether because of its beauty, its behaviour or its reflective component" (2004, p.227), the user does not necessarily feel they have a moral or ethical responsibility to care. However, in times of economic uncertainty people are willing to buy products that they can "…keep and care for and enjoy for longer periods of time", which as Fulton Suri (2009) proposes reminds us of the value of "…taking care of the things we love, and growing our love for the things we take care of." While this perspective may be reminiscent of Strasser's depiction of pre-World War II attitudes towards the use of preventative maintenance practices for 'useful' products, in contemporary society perhaps it is through the moral and ethical connections associated with, for example, duty of care with ownership, environmental issues and the much publicized social conditions of workforces that may motivate and re-engage care agendas.

Although a consumerist 'throwaway' culture is prevalent, people will often devote more time, money or attention when buying and using a product if it meets both functional and aesthetic needs. This coefficient is frequently associated with perceptions of 'special' (Cox et al., 2013). In much of the literature evaluating the bond between user and product, terms such as *special, cherished, valued,* and *treasured* are frequently used to describe the user's emotional attachment towards objects and spaces that are considered important or long lasting. These ascribed terms can also be used to reference products that have 'unknown' lifetimes, and it is difficult to determine whether the objects are used regularly or infrequently. However, products that provoke emotional and personal responses can become "…precious to us and worthy of our care" (Walker, 2006, p.49). This suggests that an object, or space, has to be valued, be special, or cherished in order to motivate the user to care; can 'ordinary' products and domestic spaces that are in regular use elicit caring practices too?

Methods

The idea that many people place a greater emphasis on functionality and reliability, over durability (Cox et al., 2013), points towards a need to better understand how products and places are cared for and maintained, and to explore the types of preventative care practices that are adopted by people. In the '*Caring for Places and Things'* pilot study an interdisciplinary team of design researchers focused on methods for revealing the ways in which caring is, or could be, embedded and expressed in the daily encounters between people and products and domestic spaces. Within our communities there are specific products and spaces that are regularly cared for and maintained by people, and using quantitative and qualitative approaches including surveys, observations and semi-structured interviews, the research team are exploring users perceptions and applied practices towards the care of products and spaces in regular use. By understanding and comparing variances in knowledge, skill and attitudes between different users, and specifically where care knowledge and skill is acquired, it is hoped that the data will begin to identify what individual and community care practices are in current use, and point to the requirements that are needed to support and promote an increased engagement with care and maintenance routines by individuals and communities.

In order to explore peoples' perceptions and experiences of caring three online surveys were proposed. At the time of writing the surveys for garments (79 respondents) and domestic spaces (38 respondents) were complete, with a product survey to follow. Ten face-to-face, semi-structured interviews with male and female users representative of a broad range of ages and socio-economic groups were also conducted. The interview participants were required to focus on the caring practices associated with either: a) a garment, or b) a domestic space, or c) a product that was regularly in use. The participants were approached through existing networks and selected to represent a wide spectrum of users at different life-stages. Each participant was provided with a short background statement that specified the study's intention to understand the care practices associated with items and spaces in frequent use. Terms such as 'special', 'cherished', 'treasured' were avoided so as not to trigger emotional engagement responses. It was decided not to highlight that the study was also interested in perceptions of product lifetimes and sustainable design, since it became apparent in question development and trials that this focus had a tendency to lead participants to choose items or specify approaches perceived as being environmentally friendly.

Findings

Although in the early stages of the study there are some observations that can be made from the data gathered in relation to garments and domestic spaces. Common themes have begun to emerge that identify some of the 'value' attributes that users associate with a specific garment or domestic space. At the same time we are beginning to notice areas of concern or difficulty that are encountered by users in respect to care practices, which may or may not be apparent to the design community.

It is commonly believed that providing and improving care information at the point of purchase is critical, and making sure that this advice is clear and simple is an important step in assisting users at home (Cox et al., 2013). However, existing studies that explore the benefit of product labelling in user care decisions have shown mixed results. This, it is argued may point to the potential to explore alternative delivery systems for the communication of care techniques beyond the traditional label. In a study conducted by van der Merwe, Bosman, Ellis, van der Colff and Warnock (2014), although the majority of survey respondents recognized the life of a textile product could be extended by following the care instructions provided, less than half of the respondents carried this through to a practical application. This observation was reiterated in our early findings, where only 40% of the garment survey respondents claimed to follow care instructions. This would support an alternative strategy from Manzini and Jégou (2003) that care may be better managed through external services and facilities that would reduce the need for dedicated space and equipment in the home, and drive the development of efficient, high quality outside services. However, it is becoming clear in our study that while it appears people may not follow formal or manufacturer's advice, many people rely on existing experiences, which may be self-taught or come from knowledge that has passed down through family members (Shove, 2003). In discussing the reasons for washing clothes, Shove argues that typically users wash clothes for personal comfort and pleasure, and to meet social expectations for wearing clean clothes, however today laundering is increasingly linked to keeping clothes, "…looking and feeling as good as they did when they were new" (2003, p.125). This was a view shared by many of our garment survey respondents. 71% of our respondents claimed to wear one specific garment 7 times or more in a month, and from comments provided in relation to their choice and use of relevant laundering and storage methods it was apparent that their caring and maintenance practices was influenced by a desire to preserve the original condition of the garment.

Similarly, people appear to have an identifiable and deliberate approach to the caring of domestic spaces that are in regular use. 69% of respondents specified a kitchen or bathroom as the space that they allocated for care, with 47% of respondents carrying out routine care practices typically more than 12 times in a month. In line with Shove's (2003) observations with the washing of clothes, it seems that the skills required to care for a domestic space are typically learned from members of the family with 97% of our respondents learning caring skills at a very young age from the mother. However many users are prepared to question and challenge existing practices especially when it comes to choosing between regular and environmentally friendly cleaning products. "Some of it I've learnt from my Mum, showing us when we were little …and other stuff I've picked up from online sources about what's an eco-way to do things.' (Becca, female, 25)

It would appear that there are specific desirable qualities sought in regularly used garments and domestic spaces that motivate users to engage with appropriate care practices. In terms of clothing products the majority of survey respondents (almost 90%) used the term 'comfort' to describe one rationale for why the garment was cared for and used regularly. From the data on domestic spaces it is apparent that for most users caring practices are associated with cleanliness. In the UK in the late 1890s a wide range of measures were implemented to change public behaviour in order to prevent the spread of disease (Forty, 2002), which included communicating scientific facts and stimulating emotive responses of guilt and anxiety about dirt. It appears, this health and hygiene agenda is still active today.

Conclusions

Although the pilot study is a work-in-progress, it is recognized that a larger study is needed to more clearly define the key desirable qualities and drivers in regularly used products and domestic spaces. Once identified these may help to signal pathways to improved design, development and/or services that can be employed to motivate users to rigorously engage with care practices again.

For the design community we reiterate the view shared by Cox et al., (2013) that there is a potential to improve signposting to after-care service and repair where it is available. At the same time it is recognized that users acquire care knowledge from family members and that it requires time and commitment to update personal knowledge. As previously discussed, existing sustainable design literature suggests that care practices could be managed through external services and facilities. However, if not handled cautiously, this approach may become problematic as the duty of care is shifted away from the user, creating a wider disconnect between product and user. But from this perspective we can see that the role of design and the designer is repositioned. Design is then not merely seen as a contributor to production, but instead it is a bridge between production and consumption. From this position we argue that another way forward is to consider design practice underpinned by care thinking as a way to support and engage the user in a more considered approach to the care of specific objects and domestic spaces.

Acknowledgments

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Upcycling as a design strategy for product lifetime optimisation and societal change

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Keywords: upcycling; textile waste; design; production; sustainability.

Abstract: Designers and product developers are taking greater responsibility for the problems presented by the inefficient and unsustainable systems used to create new fashion items. The culture of transience, newness and perceived obsolescence, so prevalent in the fashion industry, has led to growing over-consumption and consequentially high volumes of waste. Clothing is often disposed of with as much as 70% of its potential lifetime still left.

Upcycling seeks to provide a transitional solution to the textile waste problem, by optimising the lifetimes of discarded products from an inefficient system, as technology moves to develop more sustainable approaches. As a design based waste solution, upcycled fashion production utilises textile waste to create products with a higher retail value than traditionally recycled goods.
This paper aims to analyse the innovative ways in which UK based upcycling designers are recreating style and value from discarded materials, and the benefits of this process. The author's own design process, as a UK based upcycling designer, was documented and examined. Challenges and solutions to upcycled production were then further investigated through structured interviews and observational field trips with leading UK based upcycling practitioners.

The practical implications of this research include the development of an innovative, UK based sustainable design and production approach, which directly tackles the issue of textile waste and offers scope for further employment and training within the industry. Social implications include recommendations on how best to engage with the public on environmental issues in the apparel industry, and the wider implications of these issues.

Introduction

Morgan and Birtwistle (2009) and DEFRA (2009) have warned that UK landfill space is to run out in less than 10 years. In addition methane emissions created by the biodegradable waste at these sites, such as natural fibres used in clothing, are 21 times stronger than CO_2 as a green-house gas. 3.1 million tonnes of CO_2 is produced by the fashion and textiles industry every year in the UK, as well as 20 million tonnes of waste water (Minney, 2011). According to RockstrÖm (2009) the safe planetary boundary of 350 ppmv of atmospheric CO_2 has already been exceeded globally, and currently stands at 387 ppmv. The effects of this are threats to ecological life-support systems through global warming and polar ice loss.

The UK alone discarded approximately 2.35 million tonnes of clothing and textile waste in 2006 (Allwood, Laursen, Malvido de Rodriguez, & Bocken, 2006). Fletcher (2008) calculated that this equates to around 40kg of textiles waste per person in the UK, of which 74% (around 30kg per person) is sent to landfill, with 13% sent to incineration and only 13% sent to material recovery. The majority of recovered textile items are currently exported for reuse (Bartlett, McGill, & Willis, 2013). Once collected, post-consumer textiles are processed and sorted; an activity requiring skilled workers to identify and separate textiles, ready for reuse or recycling. One facility for handling such activity is Oxfam's Wastesaver Plant, which handles over 100 tonnes of textiles a week (Waste Online, 2010).

In a study by Farrant et al. (2010) the route of donated second hand clothing (SHC) is defined hierarchically, with the best pieces being resold in western markets, lower quality items exported to Eastern Europe and Sub-Saharan Africa, and the least good recycled, incinerated or thrown into landfill. The countries of Sub-Saharan Africa received close to 30% of world exports of SHC in 2001. These imports carried a total value of $405 million, up from $117 million in 1990 (Hansen, 2004). The textile reprocessing industry is however in a state of flux, as quality is reducing and volumes are increasing, creating financial imbalance.

Considering a new t-shirt (weighing approximately 250g) costing £2.65 wholesale in 2006 (Allwood et al., 2006), and allowing for inflation, around £3.35 in 2014 (Bank of England, 2014); with roughly 4000 new t-shirts in 1 tonne, new garments have an approximate value of around £13,400 per tonne (£13.40 per kg) and upwards. Bartlett, McGill, and Willis (2013) estimate that the average revenue received for a tonne of SHC & textiles is £917. Purchasing these textiles and sorting them costs a reprocessor approximately £650 per tonne, leaving just £267 profit per tonne of used textiles sold.

The concept of upcycling presents an opportunity for designers to lead the way forward, in sustainably utilising the many tonnes of textile waste produced to create increased value and satisfy the constant demand for new fashion, while technological developments advance towards more sustainable methods of production. Consumer appetite for newness has led to the current situation of over-consumption and over-production, resulting in waste, pollution and harmful emissions, as well as a depletion and exploitation of natural resources. High volumes of textile waste have been viewed as the end of the line for those discarded garments; however, the fashion industry could be utilising this resource to create well designed and sustainably sourced upcycled clothing.

Methodology

In this qualitative study, a constructionist approach to research was taken to investigate the ways in which individuals and groups participate in the construction of an upcycling process as part of their practice. Qualitative research methods were used as the study chiefly deals with participants' views of their own practice. An inductive approach was used to develop insights in order to propose hypotheses and shape theories derived from the qualitative data collected (Bryman, 2008).

The first author's own professional practice in creating upcycled denim wear was also documented in order to gain a deeper understanding of this process and to assess its effectiveness against the current practice of other upcycling practitioners. This information was then further developed by using data from interviews carried out with five UK based upcycled fashion practitioners, and one UK high street fashion label, involved in the area of social responsibility. This information enabled the identification of design and production related issues faced by upcycled women's wear producers in the UK.

Focus groups were used to gain qualitative information on consumer attitudes and behaviour. As a semi-structured, open ended interview technique, focus groups are suitable for situations in which asking questions with a general idea of topic and rough notion of sequence are known, but not fully specified in advance (Jankowicz, 1995).

Sample selection

The high street label chosen for the study was a brand which had expressed an active corporate social responsibility policy as a member of the Ethical Trading Initiative. The upcycling brands involved in the study represented the mixed range of UK fashion upcycling, from higher profile labels that have shown regularly on and off schedule at London Fashion Week, to smaller labels, which produced limited collections for loyal customer bases, mainly reached through social media.

75% of consumer focus group participants were in 16 to 35 age range, and could be categorised as being from the 'Fashion Surfers' and 'Product Wanters' categories of shoppers of young women who shop for leisure and have their own disposable income or budget for clothes. 25% of participants were in the 15 to 55 and also shopped for leisure with their own disposable income (Mintel, 2008; Monk and Mintel, 2011).

Data analysis

Data gathered through consumer focus groups and interviews with designers was analysed using content analysis techniques as outlined by Jankowicz 1995; Grbich 2007 and Flick 2011. These methods of content analysis enabled the identification of key areas for consideration in upcycled fashion design, and permitted the development of hypotheses and models. Qualitative data analysis software NVIVO was used to facilitate this method of analysis.

Findings: standard fashion design

High Street Fashion Design Process

A knitwear designer from a high street fashion brand was interviewed, and the design process within organisation derived from this data. The process is as follows in Figure 1.

The high street design process investigated for the study indicated that the designer's role at this brand had clearly defined limits of research, design and sample production, and did not extend beyond this remit. Unrestricted and trend-led yarn and fabric choices were made at trade shows, through suppliers and factories, with no sustainable options requested or offered. In the production and sample stages the designer would oversee the production of a prototype sample, then a second stage, followed by a final garment. This garment was then fit tested, signed off and sealed up to be passed along to the next stage in the design and production process. This process aligns with the first stage of the summarised process in Figure 2, in which a brief is set, research is carried out and designs and samples are created.

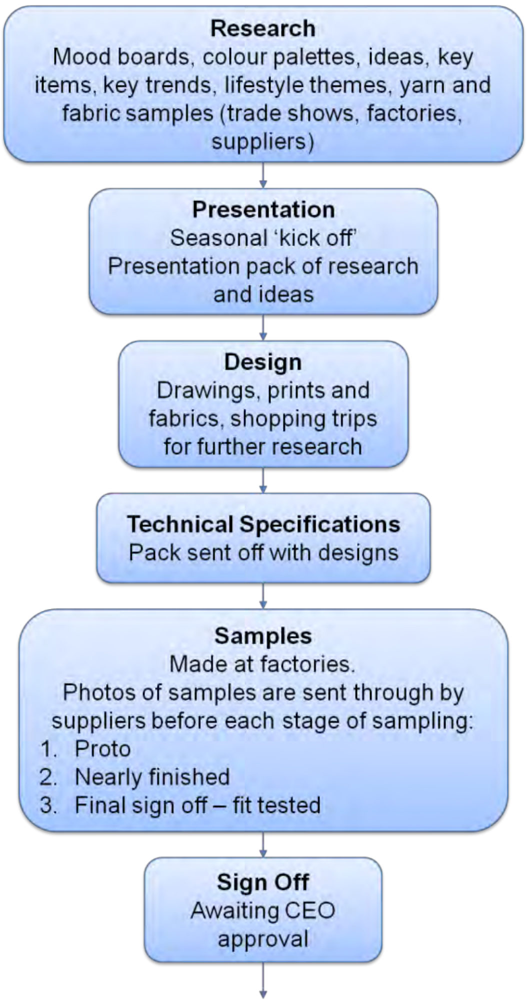

Figure 1. The High Street Fashion Design Process

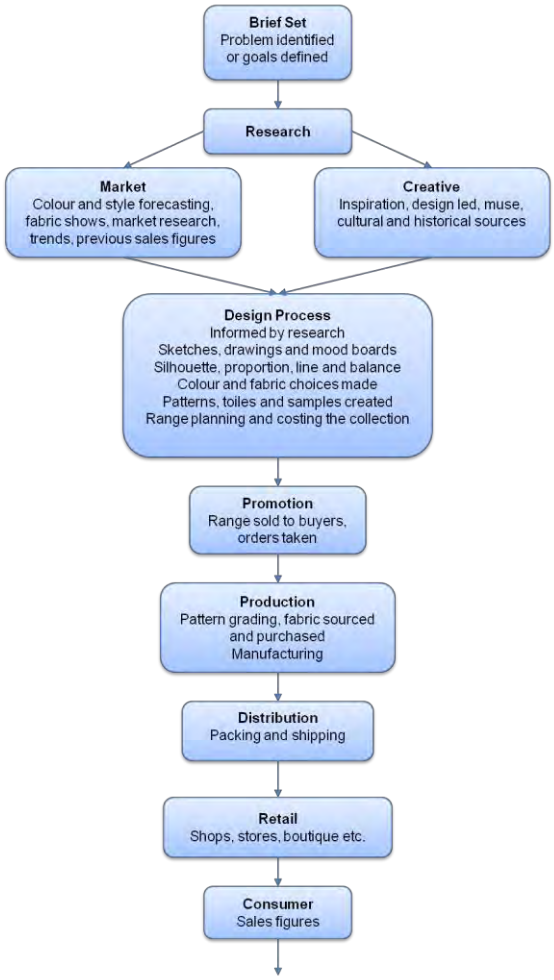

Figure 2. Summarised Standard Fashion Design Process Model. Source: adapted from McKelvey & Munslow, 2003; Jenkyn Jones, 2005; Burke, 2008; Matharu, 2010 and Armstrong & LeHew, 2011.

Standard Fashion Design and Production Process

In each of the design models examined, the process is often initiated with a brief, which outlines the design task or problem. This is then followed by research of the market and of the creative aspects of the range to be produced. The design process or synthesis phase is where the problems are solved and possible solutions ideated. This is followed by the making of sample products, which form the basis for promotion and marketing, before the products are manufactured and distributed to retailers, ready for consumers. Based on processes outlined by McKelvey & Munslow (2003); Jenkyn Jones (2005); Burke (2008); Matharu (2010) and Armstrong & LeHew (2011), a summarised design and production process model has been created (Figure 2).

Abbreviated Standard Fashion Design Process Model

From the summarised model in Figure 2, showing details of activities which occur at each stage, an abbreviated process model in Figure 3 has been created to clearly show the main stages in standard fashion design and production, including fabric sourcing. This model will be used for comparison to the upcycling model in Figure 6.

Findings: upcycled fashion design

Upcycled Denim Wear Process

An upcycled denim wear process was documented for the purposes of evaluating the main design and production concerns faced by upcycled women's wear production in the UK. This collection utilises discarded second hand denims, diverting this waste from landfill, to create designer-maker fashion products which are sold at a specialist boutique in Manchester, and through one-off events such as 'The Clothes Show Live' and off-schedule London Fashion Week at events such as 'The Good Fashion Show'. From this research, an initial upcycling process model was created for denim wear in Figure 4.

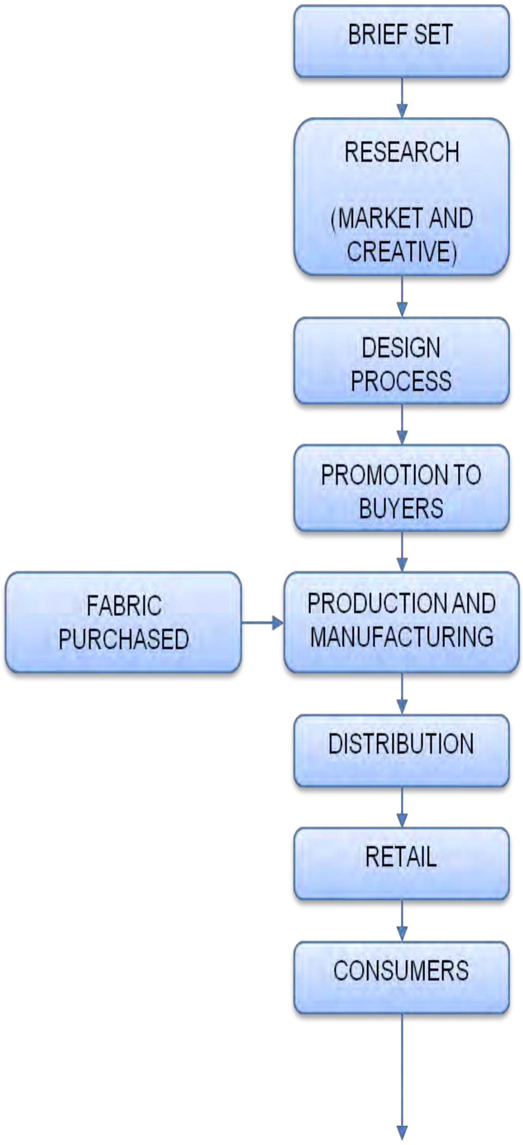

Figure 3. Abbreviated Standard Fashion Design Process Model.

Upcycled Fashion Design and Production Process

Five UK-based upcycling designers were interviewed to gain insights into the issues they faced in terms of sourcing, design, production, retail and promotion. The results from this research were combined with those from the denim wear documentation and used to further inform and develop an upcycling process model in Figure 5 (a & b).

Abbreviated Upcycled Fashion Design and Production Process Model

Following on from the development of the upcycled design and production process model in Figure 5 (a & b), detailing activities which occur at each stage of the process, an abbreviated upcycling process model has been created in Figure 6, showing fabric sourcing as it occurs at the second stage in the process. Key issues in sourcing for upcycling were consistency, quality, quantity and sorting, with local sourcing of either post-consumer or post-industrial waste textile favoured. Designs were created using traditional fashion design techniques of sketches, mood-boards and sample making, but techniques such as 'patchwork' pattern cutting created smaller pattern pieces to best utilise all available source materials. Seasonal designs often evolved slowly, taking consumer feedback into consideration.

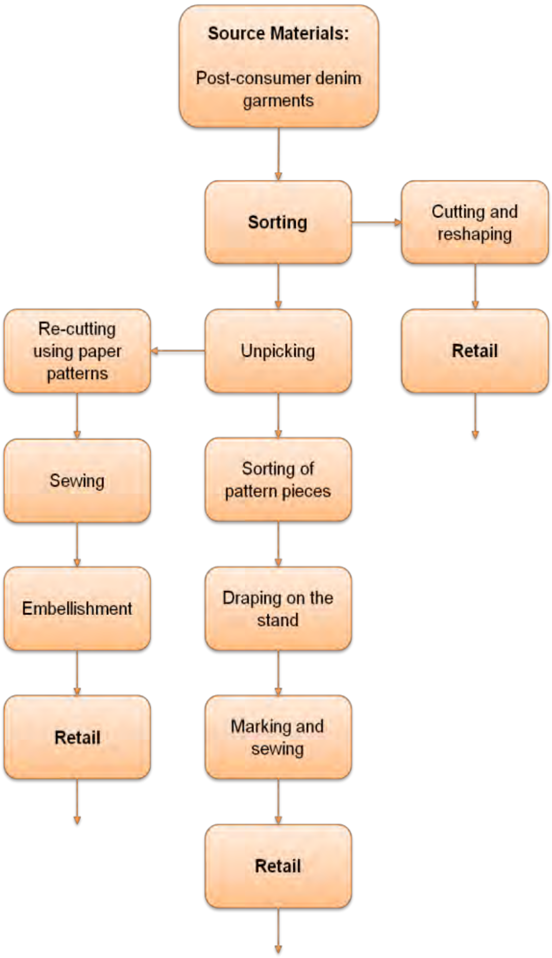

Figure 4. The Upcycled Denim Wear Process Model.

Production was often outsourced to meet wholesale orders, which were essential to the financial success of each label. Several variations on modular manufacturing were employed and relied on well planned production schedules and highly competent makers. Deconstruction was considered too time consuming, leading to a price increase for consumers, who accessed upcycled designs through e-commerce sites and specialist boutiques. Favoured promotional tools were social media and websites, allowing designers to identify themselves with distinctive branding and styling. Trade shows featured highly as effective means to gain wholesale orders, and celebrities were mentioned as editorial and headline grabbing promotional considerations.

Collaborations and consultancies with larger brands enabled designers to promote their labels though media coverage and to implement sustainable design strategies with high profile retailers. Community engagement

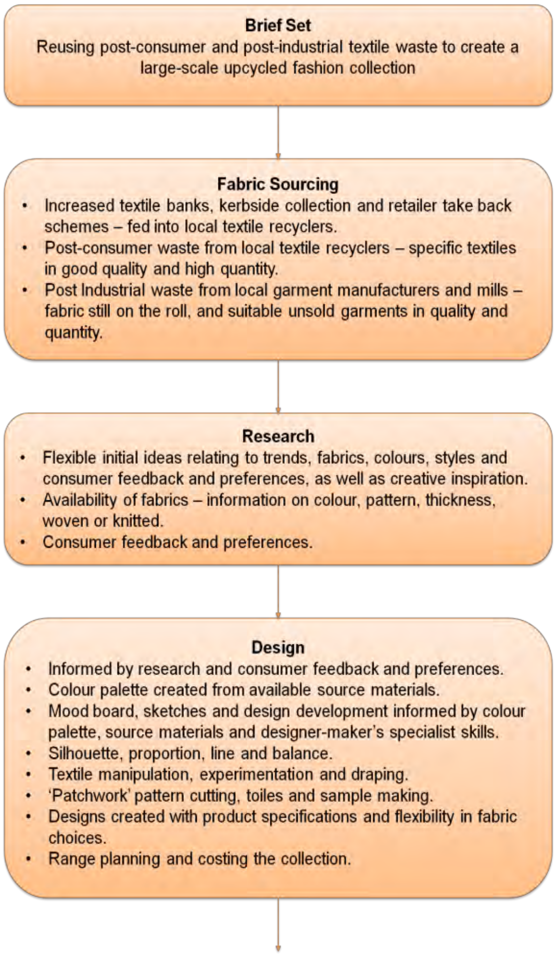

Figure 5a. The Upcycled Fashion Design and Production Process Model.

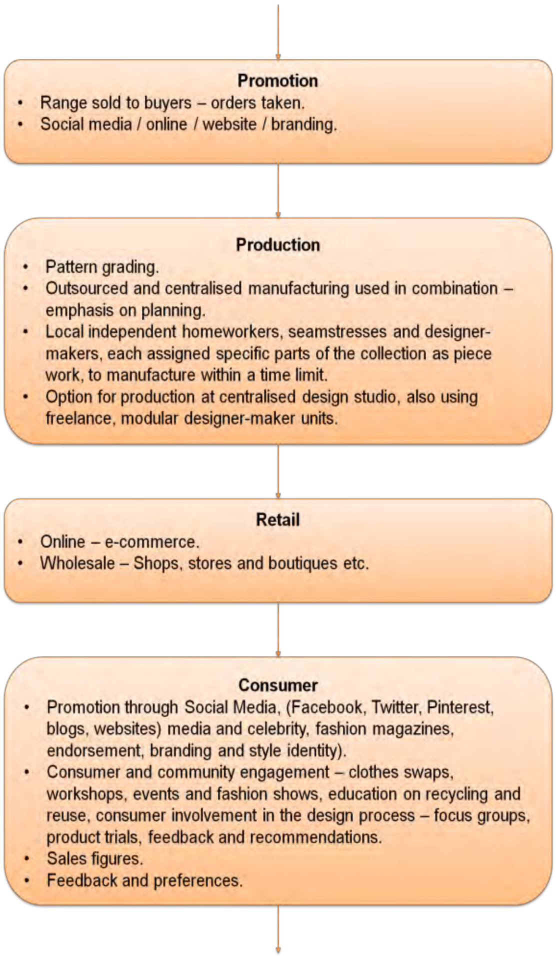

Figure 5b. The Upcycled Fashion Design and Production Process Model.

and involvement with education enabled designers to raise the profile of their brands; and to facilitate public understanding of sustainability issues with the apparel industry. The sustainability ethos of each brand, which encompassed reducing consumption, diverting textiles from the waste stream and supporting local communities; ran through every aspect of their design and production process as a common thread.

Findings: consumer perspectives

In order to evaluate the main consumer related issues faced by upcycled womenswear production in the UK, three consumer focus groups were interviewed to gain insights into the attitudes, perceptions and behaviours displayed concerning wardrobe, shopping, fashion, style and sustainability. This qualitative data informed the final analysis of all the results pertaining to the upcycling process proposed in this research.

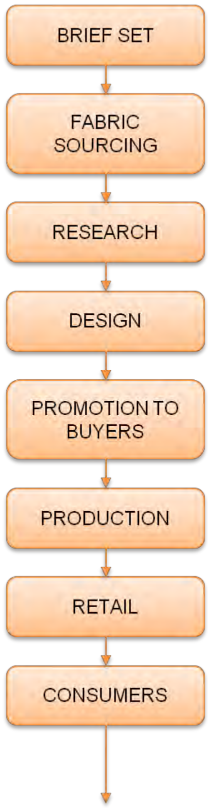

Figure 6. Abbreviated Upcycled Fashion Design and Production Process Model.

Wardrobe and shopping habits

Dresses were found to be garment of choice to wear and to purchase, and versatility was found to be a key quality for wardrobe items amongst all the consumers. Style and price were the most important considerations for making a purchase. Shopping was often cited as a leisure activity, treat or emotional boost, with high street, vintage, charity and online stores favoured amongst the demographic sampled. Online shopping was often favoured by consumers who had negative experiences of high street shopping. Trends were also viewed negatively; however style and high fashion were more highly rated.

Perception of fashion and upcycling

Sustainable fashion held associations of very basic and uninteresting styles for many; with additional negative associations of 'hempy' and 'hippie' styles. Confusion over terminology and labelling was a frequent theme throughout each of the focus groups and more clarity was called for by consumers. Upcycling was a term most consumers were familiar with, in terms of re-working post-consumer garments.

Consumers felt that if the style, price and clear labelling of upcycled styles were all present then purchasing would be probable. Internet promotion and features in regular fashion magazines were felt to be the most effective methods communicating ethical fashion information to consumers; integrating sustainable apparel alongside regular fashion and increasing the accessibility to all consumers.

For consumers, accessibility was an important factor for eco-fashion purchases, and it was felt that if it were offered alongside regular fashion, on the high street, in shops, concessions and in magazines, and integrated alongside regular fashion choices as a viable alternative, they would be more inclined to buy.

Discussion and analysis

Figure 7 was created to identify points of divergence between standard fashion design and production and upcycled fashion design and production processes. The main differences between the standard design process and upcycling process occur at the fabric sourcing stages. Key differences also occur in the retailing of upcycled fashion products to consumers with an understanding of their ecological provenance.

Fabric sourcing occurs early on in the upcycling process, immediately after the brief is set. Often the brief is directly connected to sourcing, and relates to the production of a fashion collection utilising textile waste. This is in contrast to the standard design process, where fabric purchasing occurs as a pre-production stage much later on, after research, design and orders are taken. A restricted choice in upcycling, sourcing solely from pre-existing textiles not only limits the quantities of waste directed towards landfill, but utilises a source material which does not rely on the production of virgin materials or any further heavy processing.

Designers within an upcycling organisation take on a highly centralised role, in which they either directly oversee or actively perform all duties from sourcing, design and production, through to promotion and retail. Upcycling brands and retailers make their relationship with consumers a priority; offering events which engage consumers in the ethos and lifestyle of sustainable fashion. Upcycling brands often strengthen this relationship with consumers by including interactive social media as a key element of their promotional strategies, along with a strong online presence through their own e-commerce sites.

Conclusions

The results of this study demonstrate that there are significant differences between upcycled and standard fashion and design and production processes. For effective upcycled fashion design to occur, specific considerations need to be made as part of the design and production schedule. Fabric sourcing must occur much earlier on in the process than in standard design and production, and pattern cutting techniques must take into account inconsistencies in supply with interchangeable fabric options. It is necessary for information on the availability of source materials to be on hand from the outset, in order to achieve consistency of design throughout production.

The benefits of upcycling include using waste as a source material, diverting it from landfill, and in doing so reducing carbon emissions and other negative environmental impacts. This creates a cost effective reuse of scarce resources and the embodied energy contained from initial manufacture. Upcycling provides opportunities for further training and education in the fashion and textiles industry. Employment in this sector is currently dominated by retail, with declining provision for training in areas such as manufacturing and entrepreneurship (British Fashion Council, 2010; Skillset Textiles, 2010) . The UK has the chance to fill in skills gaps currently faced by new entrepreneurs with the provision of training within upcycling businesses. Upcycling also supports economic localisation, by utilising locally sourced materials, work force and skills, plus adding to the development of local communities by engaging with the public through activities connected to sustainable consumption, skills sharing and education.

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The joy of vacuuming? How the user experience affects vacuum cleaner longevity

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Keywords: user experience; product longevity; brokenness; vacuum cleaners; cleanliness.

Abstract: An apparent reduction in the average lifetime of vacuum cleaners is explored in this paper in relation to their perceived usability and increasingly frequent product replacement. Motivations for product disposal combine perceived and real product failure with a perceived or real improved product offer. From an historical perspective, vacuum cleaners typify this pattern, continually offering a ‘cheaper and improved’ product.

Vacuum cleaner manufacturers reinvigorate the sense of satisfaction and revulsion associated with extracting dirt from our homes through new performance focused product development. For example, increased motor power, filtration, bag-less machines and clear bin compartments have all acted as sales drivers, whilst cost effective materials and offshore and more efficient manufacturing have reduced purchase prices. The latter, cost-driven, processes can create machines that are more likely to be functionally and aesthetically damaged in use, reinforcing the trend for faster replacement. The market appears likely to continue to focus on improved user experience, with growth in market share for lighter weight cordless battery powered machines posing the risk of an increased environmental burden.

Drawing from qualitative and quantitative research undertaken for a study for Defra, we explore the user’s relationship to the product, investigating the frustrations and joys of vacuum cleaner use and ownership. The findings illustrate that the revulsion and attraction of cleaning, as well as the tedium and satisfaction fostered by the product, have direct implications for vacuum cleaner longevity.

Introduction

From their invention vacuum cleaners have been sold on their ease of use and effectiveness. They have been envisaged as almost ‘magic’ cleaning machines. Jackson (1992, p. 166) reports on an advertisement promoting the first vacuum cleaners from the 1920s suggesting that they offer, “easy, effortless cleaning of every nook and corner” and provide “leisure and freedom.” She concludes: “this reveals something of the mythology of the ‘mechanical servant’: it is as if the vacuum cleaner steers itself around the house unaided” (*ibid*).

From the early 1920s Hoover advertisements through to the most recent G Tech commercials, the vacuum cleaner is still advertised as creating enjoyable experiences where before there was only cleaning drudgery Stoppani (2012). Schifferstein (2008) asserts that creating an enjoyable product experience is a principal method of enhancing emotional attachment to a product and argues that the products to which we are most attached should be the ones we keep for longer. He describes product pleasure as combination of product meaning, monetary value and utility, and attachment as the strength of the bond these factors create that affects our willingness to dispose of the product. Yet it appears (WRAP 2013) that vacuum cleaners are being disposed of after a shorter period of use than ever before, which implies that vacuum cleaners are either not as enjoyable to use as promised or that this positive use experience does not last. This disparity is significant because of the resulting environmental burden of vacuum cleaners,

disposal accounting for the second largest embodied GHG emissions of electrical products after televisions, largely because of high sales volumes (WRAP, 2012).
As part of a project commissioned by the Department for Environment, Food and Rural affairs (Defra), investigating motivations for product disposal, this paper draws on the qualitative and quantitative data collected, focusing on responses relating to the experience of using a vacuum cleaner. This includes data from 114 on-street questionnaires, 9 in-home interviews, 507 online interviews, a co-creation session with 30 participants and a focus group with 15 respondents, in the UK, between March 2014 and January 2015.

The main objectives of this paper are to investigate the effects of user experience in purchase, use and disposal of vacuum cleaners and how designing for enjoyable product experiences might increase their longevity.

Cleaning practices

Do wider cleaning practices affect whether people find vacuuming a satisfying, or even a joyful, experience? MINTEL (2013) reported that younger people (25-34-year-olds) are more likely than older people to get satisfaction from doing household cleaning and a survey by Electrolux (2013) claimed that a third of vacuum cleaner users in the UK - especially women - feel satisfied after vacuuming.

These surveys suggest that some people do enjoy vacuuming, though this is not as universal as advertisers suggest. Our study found that although nearly 40% of respondents in the on-street questionnaire wished that someone else would clean their house, a majority did not. What types of people are in this 60% who might enjoy vacuuming?

Vaussard et al. (2014) identified four sets of cleaning habits based on the motivation a household shows to keep their home clean, the efforts made and time spent on cleaning. These have been adapted in our research to categorise types of cleaner, as follows:

1. *Spartan Cleaners*, vacuum less than once a week and consider cleanliness of their house a medium or low priority
2. *Minimal Cleaners*, vacuum once a week or, if less often, consider cleanliness of their house a high priority
3. *Caring Cleaners*, vacuum at least 2-5 times a week and consider cleanliness of their house a high or medium priority
4. *Manic Cleaners*, vacuum daily and prefer to do it themselves rather than employ a cleaner.

These cleaner types were recognisable in the in-home interviews, particularly the Manic cleaners who enjoy cleaning and require their vacuum cleaners to function in a way that completes it to a high standard. One Manic cleaner interviewee reported vacuuming every day to relax after work – perhaps the ultimate enjoyable task. In contrast, the ‘Spartans’ we interviewed aimed to complete their vacuuming in the shortest time possible, though people across all the cleaner types reported getting some satisfaction from vacuuming. This suggests that there is satisfaction in using an efficient vacuum to collect both obvious and invisible dirt – pleasure in sparing oneself from filth.

The enjoyable purchase experience

MINTEL (2010) ranked factors that consumers report influencing their purchase of a vacuum cleaner. Our work has suggests that three of the top five factors relate to the overall experience of using the machine alongside specific, measurable performance criteria:

1. Suction power
2. Easy to move around
3. Lightweight
4. Easy to store
5. Suitable for hard and soft surfaces

Purchase decisions are also informed by people’s confidence in the product. An interview conducted for the project with a vacuum manufacturer confirmed that guarantees are important sales drivers, especially for premium products although they are not necessarily used by consumers if a product does fail.

Alongside guarantees, this manufacturer highlighted consumer reviews as important for sales. Reviews reassure consumers about both enjoyable experience and function and they were identified as particularly important with purchases online or untested from retailers. These factors, along with flexible return policies, help to encourage enjoyment of a product and avoid the cognitive dissonance that Wood (2001) describes as damaging to the consumer - brand relationship when products do not meet advertised expectations. These relationships are intrinsically linked to cost and can be maintained with consumers in spite of product failure or disposal when consumers achieve their perceived product value.

The enjoyable use experience

A workshop with vacuum cleaner users was held to explore methods for prolonging the machines' lifetimes, including these notions of vacuum cleaning enjoyment. Participants were asked to describe their most frustrating and most enjoyable vacuum cleaners. The workshop sought more detailed data about factors influencing purchasing decisions than that collected in market research by MINTEL (2010).

The workshop task allowed groups of participants to draw on their own experiences. Provided with simple line drawings of an iconic upright and cylinder vacuum cleaner they were encouraged to work together to annotate and adapt each drawing (Figure 1).

Participants indicated that they considered vacuum cleaning most enjoyable when using a machine that is easily manoeuvred (e.g. lightweight and cordless), user-friendly (e.g. easy to take apart), adaptable (e.g. including accessories), requires low maintenance (e.g. easy to empty and repair), powerful (e.g. high suction performance) and appealing (e.g. smooth aesthetic and sensible price).

By contrast, participants felt that vacuum cleaning was most frustrating when the machine was difficult to manoeuvre (e.g. heavy, wobbly and unstable), not user-friendly (e.g. noisy and difficult to store), required complex maintenance tasks (e.g. emptying from the bottom and disentangling hair from the brushes), lacked in suction power, was visually bulky and attracted dust and scratches. A summary of their discussions is shown in Table 1 and a characterisation of one group's experiences is shown in Figure 2.

Respondents to the subsequent online survey were given a hypothetical scenario of purchasing a 'totally new type of vacuum cleaner' and asked to rank five types of innovative designs.

The proportion of 'top' rankings by the survey respondents were as follows: vacuum cleaners that were maintenance free (59%); machines that communicate their performance (23%); a rewarding experience (9%); looking good as it gets older (6%); resale value on replacement (3%). These preferences were confirmed by and explored with the focus group, identifying real time performance information as specifically appealing.

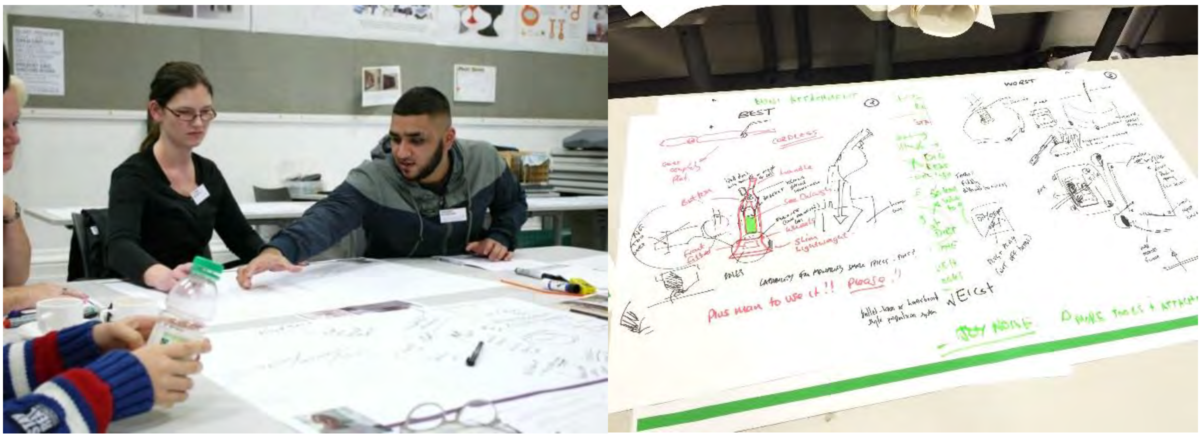

Figure 1. Workshop participants discussing and sketching the most frustrating and most enjoyable vacuum cleaners (left). The resulting sketches (right).

Most frustrating vacuum cleaner	Most enjoyable vacuum cleaner
Manoeuvrability	
Bad mobility	Ball wheels
Heavy	Easy to move
Unstable and wobbly	Cordless
Loose cable	Fits in corners
Excessively long hose	Lightweight
Short cord	Long cable
Small wheels	
Hard to drag around	
Rigid hose	
Square wheels	
User-friendliness	
Difficult to store	Easy to store
Small capacity	Large capacity
Difficult to assemble	Easy to take apart
Hidden features and parts	Clear plastic
Noisy	
Scares children and small animals	
Adaptability	
Too many tools	Lots of nozzles
Loose parts liable to be misplaced	Interchangeable tools
	Multi-application tools
	Compact but extendable
	Able to charge mobile phones
	Removable ‘Dustbuster’
Maintenance	
Empty from bottom	Easy to empty
Paper bags	Compresses dust into bales
Not repairable	Easy to repair
No replaceable parts	
Repaired and held together with sticky tape	
Dust and hair gets caught in brushes	
Performance	
Lack of power	Powerful
Poor suction	Satisfaction through excellent suction
No suction	
Appearance and Price	
Bulky	Smooth aesthetic
Catches dirt in edges	Strong, smooth material
	Thin, slim line body
	‘Sensible’ price

Table 1. Summary of ‘Most Frustrating’ and ‘Most Enjoyable’ features for a vacuum cleaner.

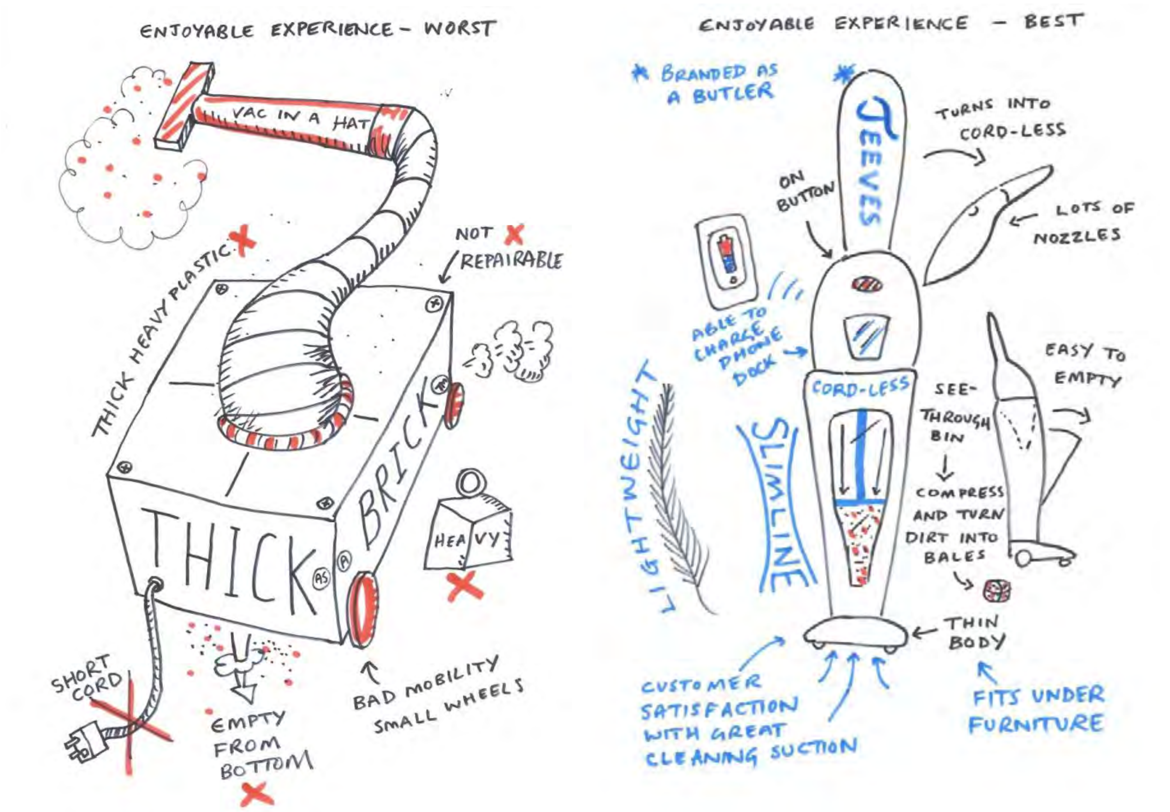

Figure 2. Examples from user workshop of features of most frustrating (left) and most enjoyable (right) vacuum cleaners (Enjoyable Experience theme group).

Vacuum cleaner disposal

In the current vacuum cleaner market, where product lifetimes appear to be decreasing, motivations for disposal become inextricably linked with motivations for purchase. If vacuum cleaners are advertised on the basis of 'enjoyability' but come to be perceived as less enjoyable, are they then more likely to be disposed of? Vacuum cleaners have a high level of ownership: 87% of the UK population in 2009 (MINTEL, 2010). This points to a market near saturation and facing a contraction of sales, which may require manufacturers to create methods for triggering replacement purchases. MINTEL postulates in the report that this may include improving the product longevity offering for some brands. Most people only report replacing their vacuum cleaner when it fails. MINTEL (2010) stated that 80% of people would only buy a new vacuum cleaner if their old one broke down. These may include products that are cost effective to repair (Which?, 2014a) or suffer a perceived loss of function, possibly from poor maintenance leading to worn or blocked filters, as we discovered through systematic vacuum cleaner 'teardowns'. Our online survey provides more detail on what consumers consider as motives for disposal:

- The most common reasons for respondents ceasing to use their previous vacuum cleaner are because it stopped working efficiently (44%) and did not work at all (34%).
- Spartan cleaners are less likely to replace their vacuum cleaner due to reduced efficiency (33% compared to more than 40% for other types of cleaner), perhaps because they are less worried by a risk of having a machine that does not perform well or fails completely.
- 16% of respondents replaced their vacuum cleaner because they wanted a new one, despite their existing one still working. Replacement for this reason is more likely among those who are young (22%) or in a higher social grade (21% for AB level), and less likely for Spartan cleaners (8%) compared to other cleaners.
- When disposing of their old vacuum cleaner, 14% of respondents gave it away and an identical percentage still had it at home, suggesting a significant number of old

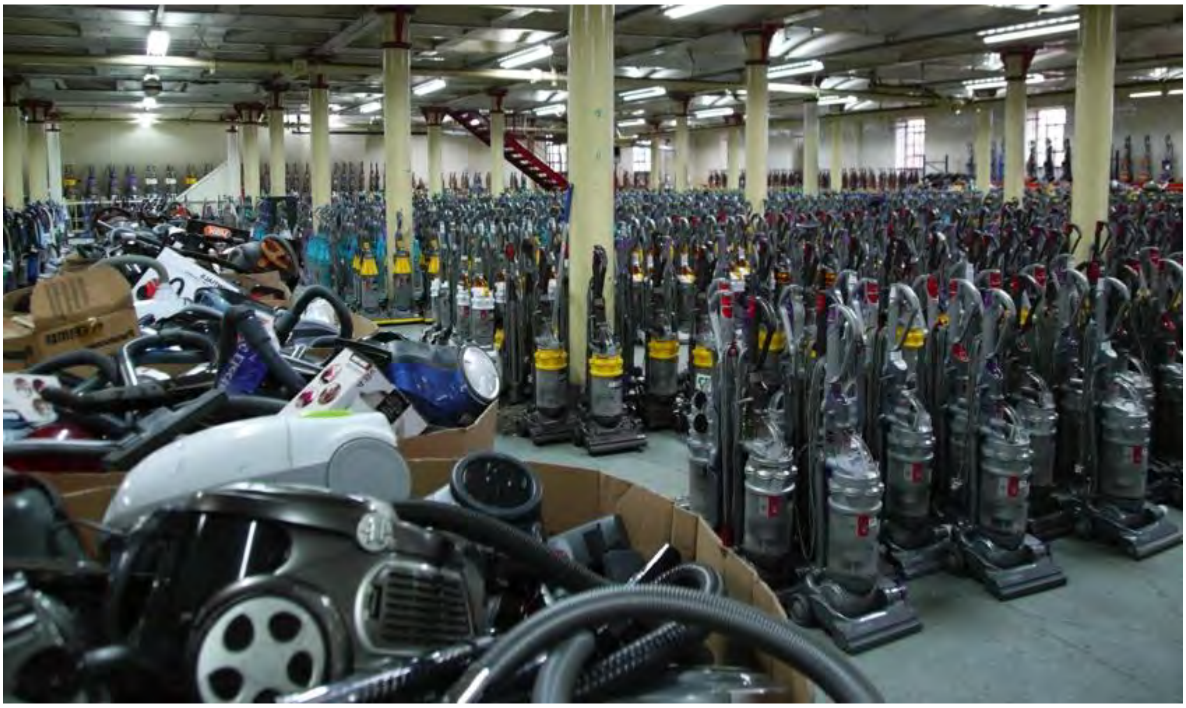

Figure 3. A selection of traded in vacuums at an auction house, the majority according to the vendor in good working order.

machines that are still operational or with which owners have a degree of product attachment.

These results suggest that any loss of real or perceived function acts as a driver for product replacement. Respondents who replaced their vacuum cleaner because it did not work efficiently or wanted a new one indicated a lack of confidence in, or emotional attachment to, the product, i.e. the product has either ceased to be useful because it has become less enjoyable.

Visible wear reinforces this loss of real, or perceived function. The plastic materials used in most modern vacuum cleaners show this wear in characteristic ways with particular consequences for longevity. Plastics are relatively soft, allowing the surface of a vacuum to acquire scratches and grazes; transparent plastic that starts life with gloss shine becomes opaque and 'milky'. The electrostatic properties of plastics mean that the very fine dust that a vacuum cleaner collects will be attracted to the surfaces of the casings, which are often made in complex shapes that are not easy to clean. These qualities are liable to lead to disaffection with plastic products, even to the extent of encouraging disposal of products that are still functional. This is particularly the case in respect of products that have connotations of hygiene (Fisher 2004, Fisher and Shipton 2009) The use of plastic along with advances and changes in manufacturing have dramatically reduced the cost of vacuum cleaners. The first vacuum cleaners imported to Britain cost £25, equivalent to a maid's annual wage (Jackson 1992). Nowadays prices are, in real terms, considerably lower[1], perhaps 1% of an unskilled worker's annual wage. According to the White Goods Trade Association (WGTA 2010), over the last two decades appliance prices have dropped in real terms, with significant implications for the industry and for product lifetimes. Brook Lyndhurst (2011) identified the low price of replacement products as a significant barrier to extending the lifetime of 'workhorse' products. Consumers can therefore feel they have had value from a product after a shorter period. Reduced cost allows for psychological obsolescence (Cooper, 2004), illustrated by consumers who do not make use of a warranty to which they are entitled or simply

[1] According to Which? (2014b), the average cost of a new vacuum cleaner is £184, rising to £279 for a Best Buy.

dispose of a product before it is functionally obsolete. Cost therefore, has become the significant barrier to consumers pursuing longer lasting products and, additionally, Cooper and Mayers (2000)[2] identified a consumer concern that products may become 'out of date'.

Our interview with a vacuum cleaner manufacturer identified that product sales benefit from psychological obsolescence rather than a technical product failure that could damage a brand. Vacuum cleaners perhaps typify the practice of psychological obsolescence where manufacturers offer an innovative, fashionable new product that delivers a potentially better result within the previous products' guarantee period.

Conclusions

Notions of enjoyable experience are significant in new purchases and, by association, may encourage premature vacuum cleaner disposal. Our consumer interviews and product teardowns show that consumers are not, in the majority of cases, disposing of vacuum cleaners because they are irrevocably broken, but because they either perceive a loss of function or that repair will be inconvenient.
Increasing a user's emotional attachment to the product through new product development has the potential to overcome some of the barriers to vacuum cleaner longevity. The user needs to know that their vacuum cleaner is performing effectively. The online interviews and focus groups suggested that this could be facilitated by reassuring the consumer through real time information. Longest lasting vacuum cleaners would, therefore, not only have robust design and engineering, but also combine the reassurance of recurrent performance information with genuine usability.

Acknowledgments

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Global perspectives and translations of consuming clothing waste in the present

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Keywords: clothing waste; second hand clothing; sustainable design; consumerism.

Abstract: The mass consumption of clothing has resulted in collection charities such as Oxfam exporting unwanted second hand clothing to markets in the Sub-Saharan region. This is a trade that is seen as supporting sustainable solutions to unwanted clothing but offers 'both opportunity' and 'danger' to local communities (Haggblade, 2007). The research explores the second hand clothing trade in Ghana, which evidences this danger and challenges the notion of opportunity.

The second hand clothing market whilst benefitting local communities in Africa has also impacted upon local textile production. From our conversations around these issues, a collaborative project idea emerged entitled 'Return to Sender'. The project aims to highlight and challenge the effects of the second hand clothing market upon local heritage in Africa. A shared perspective through global design stories can encourage designers to understand the consequences of design but at the time same enable them to have the power to impact and drive change of consumer habits. The current and future perspectives of purchasing clothing and re-use is explored, regarding how this could then influence and change the global second hand clothing markets.

This paper also explores the potential of sustainable outcomes through focusing design in the present, rather than the future. In order to understand a global world we need to see the world as it is to solve the problems and in turn prevent problems in the future. We need an approach that is not engrained into a system but something that promotes creativity and openness to change.

Introduction

This paper has developed through an ongoing conversation between three academics, who have collaborated to evolve thinking and experience; using a shared approach to develop an understanding of global perspectives on second hand clothing, sustainability and consumerism. Design is used as a central focus and presents the conversations and exchange of shared knowledge on sustainable clothing design practice and the global concerns in relation to clothing waste.

Over the last 15 years fashion has become faster and cheaper (Black, 2008). With the use of online purchasing, fashion clothes can now be accessed by the consumer at any time. The rise of digital technology has created a culture where owning and accessing makes it possible to buy 24-7. This has developed a mind-set of a need for more; all of the time.

Second hand clothing in the UK

It is evident that sustainable practice is emerging in the UK through second-hand clothing markets together with fashion retailers and charity initiatives being introduced. This still raises questions upon its sustainability long term; how much of this unwanted clothing is actually worn and more importantly what impact does it have on emerging fashion manufacturing companies within local communities? UK designers are educated to design and develop new innovative, creative clothing ranges and retailers use marketing strategies to encourage consumer purchasing. New clothes are designed that are positional and will shortly become obsolete. (Brooks, 2015). Changes to the way the UK supplies, uses and disposes of clothing could reduce the carbon, water, and waste footprints of clothing consumption by 10-20% each year (WRAP, 2012).

Many UK retailers are now adopting sustainable business initiatives; Marks and Spencer's (n/d) (Shwopping) and Hennes & Mauritz (n/d) (Conscious Collection) both support clothing charities such as Oxfam. Much is still unknown about how sustainable this practice is and emerging evidence is indicating that donating unwanted clothing to charities can be damaging by preventing growth in new business for African fashion companies due to high volumes of unwanted clothing being donated. Although new initiatives are being set up to account for the growing waste, this also demonstrates how fast fashion over-produces clothing which fuels the turnover of over-consumption. Econmodo (n/d) reported 80% of stuff we own is used less than once a month. (http://en.ecomondo.com). In 2013 a study by WRAP into consumer second hand shopping, identified 27% would have bought them new if they could not find them second hand. A report in 2011 by Mintel produced a survey, showing 44% of participants intended to decrease the amount of stuff they buy.

Designing for disassembly and re-use for innovative enterprise

Through questioning different design and re-distribution approaches consideration to the importance of encouraging design students to explore new and existing methods that encourage the longevity of clothing became evident. Highlighting opportunities that could be utilized within the design process and end use, considering new ways of working that are sustainable for designers, industry and charities.

Industry

Niche companies such as Junky Styling in the UK have developed a sustainable business model of a wardrobe surgery consultation/ procedure/result (www.junkystyling.co.uk). Designer Christopher Raeburn produces garments by reworking unused and vintage military garments into contemporary outerwear (www.christopherraeburn.co.uk).

The company Re-Shirt; have re-invented re-distribution of a t-shirt, using technology and the social aspects of fashion to embed the wearer's life of the garment. This embodies a perceived value of the garment and builds upon a connection to a wider like-minded community. They describe Re-Shirt as "a way of keeping valuable cotton resources in circulation, providing information related to the cotton backstory, based on the idea of artefacts embodying historical narrative, adding tangible value and meaning to an existing T-shirt through the intangible value of storytelling. (Atlier, 2008).

Charities

Good examples of a workable business models with second hand clothing donation include the Oxfam project in Senegal called Frip Ethique (n/d), designed to provide employment and generate a profit from unwanted clothing. This is then invested in livelihood programs run by Oxfam in West Africa. It involves local women, who sort and sell clothes donated to Oxfam to local market traders. The profits are also invested in Oxfam's work fighting poverty in Senegal. TRAID also demonstrates different approaches to making change within how to provide solutions for second hand clothing waste, utilizing opportunities for conversation, collaboration and learning to instigate change. An example of this can be seen within their project initiative with Fabrication which uses Upcycling Workshops to add value through creativity and design, stating "items too damaged for re use present an opportunity for transformation". They take inspiration from 'Cradle to Cradle' thinking, to "imagine a garment circulating through many owners in its lifetime." (www.traid.org.uk).

The key insights gained from these examples demonstrate the relevance of focus being directed to create easily the replacement of things by customizing, fixing and repairing in a bespoke and user specific way. Customising and mending design to exact needs in order to repurpose and in-turn not create waste; encouraging and enabling the longevity of a product.

Second hand clothing in ghana

The economy continues to play a major role in influencing the buying patterns of the receiving nations of second hand clothing. Poverty has been a contributing factor in creating the explosion in the second-hand clothes sales in sub-Saharan Africa. A single parent with two children under the age of 10 who is a final year student on the Bachelor of Technology in Fashion and Textiles stated:

"I have two children and have to pay school fees for them and myself because their father does not support in their welfare. I have to work full-time as well as study. The reason why I am on the course is that my current job is not in fashion, I work as a customer service assistant for a telecommunications company. I feel I have no future in that and fashion will be good for me as I can work for myself and teach with my qualifications, so that I can take better care of my family. So you see, why won't I buy second-hand clothes? I can dress myself and my family very well for little money, I can get my size and not have to worry about alterations, and people will not look at me and judge me for being a single mum and children will not be laughed at for not dressing well. Even if we have no food to eat, no one will know but if we don't have clothes to wear will be found out that we are poor."

When two Ghanaian male youths were asked to state what the average life span of clothing item was, they replied with the following responses: (Langevan and Gough, 2012).

"I have two ways of looking at this, firstly, life in Accra is very tough and therefore I must wear my shirt for example until it fades out and the fabric loses its strength. Even after this stage, I can pass it on to a distant family member in a rural area and it will be "new" for him. When seen as new for the distant relative, he will wear it for some time before he uses the much worn out shirt as "working gear".

"I have different clothes for different occasions being formal and informal wear. In the case of my formalwear which I may wear for church and parties for example, when it becomes old for me, I will then begin to use it as casual wear for college or for work before I pass it on or mend holes in them as a fashion statement."

The irony of the findings was that even within Ghana, the notion of one man's food is another man's poison applies. When these second-hand garments have been used by the wearer, it has further beneficial uses from an urban setting to a rural area. In addition, the fashion student may wish to use the torn, over used garment for a fashion project to promote sustainable fashion.

As the conversation evolves into education and knowledge sharing, the dissatisfaction of Ghanaians towards the growing decline of the African fashion industry has become poignant.(Hanson, 2000). The question asked is, can this ever stop? How would this impact on the masses who detests the effect on fashion design and entrepreneurship and yet, these very people depend on the SHC to survive? It has therefore become a necessary evil in Ghana.

Fashion entrepreneurship: the future of fashion in Africa

The findings revealed that although a vast majority of fashion students buy second-hand clothes, they would be happier to have the skills of entrepreneurship incorporated into the education curriculum to support the sustainability of their future practices as designers in Africa. Though opportunities for entrepreneurship education have declined severely in Ghana, Langevang and Gough argue that education is the answer to "individual social success."

Fashion entrepreneurship education is key in transforming the thinking of the future fashion generation in Ghana and Sub-Saharan Africa.

Pre-pilot project

As a pilot concept to test ideas, the fashion students from Accra Polytechnic worked on the 'Think Green' Project using items such as brown pattern paper, second-hand curtains and bed sheets to re-design outfits. Students were given a pile of 'waste' to look through and select to re-design something new. One group chose old zips from used, torn garments and re-designed a mini collection of outfits using different coloured second-hand zips.

The Return to Sender Project Concept

From the conversations and discussions on fast fashion and second hand clothing in the UK and Ghana, a collaborative project idea emerged entitled 'Return to Sender'.

The aim of the collaborative design project is to investigate global approaches to exploring design for disassembly and re-use for innovative entrepreneurship. The concept of the project was based on the Oxfam Flip

Ethique model. The aim of the project was to encourage UK design students and Ghanaian design students to re-design and develop garments for first and second life, challenging a more sustainable design approach. Ghanaian

Students will utilise the second hand clothing, using their heritage and design individuality. These garments will be sent back to the UK where students will design how this continuation could be incorporated from a first design stage, to consider different contexts and needs. Clothing will be used as conversation starters between two countries, creating global dialogue that considers impact and builds future understanding for sustainable measures within global transition.

By each student understanding the phases and lifecycles that clothing passes through, a shared narrative allows the opportunity to combine design thoughts and action to determine positive change.

Project brief - return to sender

The project was set as a collaborative design project for UK and Ghanaian Fashion design students. Six fashion design students, three from Ghana and three from the United Kingdom were selected to allow shared thinking and approaches to design and produce clothing that is long lasting. For the benefit of ethics, consideration was given to the Ghanaian students due to limited resources available to them. An allowance was given to each student for their transportation and other expenses. The project aims to explore sustainable design methods that could be developed to change the model of the second hand clothing industry in both the UK and Ghana. The second hand clothing industry whilst seen as a sustainable approach to eliminating clothing waste has many unsustainable features and damaging effects.

The project provides selected students a unique and engaging learning opportunity, and it allows designers to share their knowledge and experience of design processes in different nations.

The project brief

The project brief encompasses three stages:
Stage 1 - Ghanaian students were required to purchase a second-hand clothing item, not worth more than £2.00 in pound equivalent. They then set out to re-design their selected pieces by recording the entire creative/design process. The students up cycle /customise/ reassemble the second hand clothing utilising their heritage and long view to create continuation of life for each garment. This would make the purchase of second hand clothing more desirable. Through the design process students use second hand clothing and materials identifying problems, exploring ideas for superior re-purposing and making suggestions for change to be included for first design. UK students use this knowledge and practice to design transformable garment concepts, using the inspiration from how these second hand garments have been re-contextualized, to incorporate a built in longevity for future life at first life stage.

Stage 2 - This stage requires UK students to film their design process. They talk through the process and highlight examples of sustainable practice. Reflection on expectations as to what happens to garments once they are no longer worn will also be considered.

Stage 3 - Digital dialogue - on completion of stage 1 and 2, a global conversation between the students to discuss their findings and a skill sharing of ideas is to take place via social media.

This would open up an opportunity for dialogue for all students to consider garments as conversation starters, to share perspectives and build a language of sustainability for now and the future. This first would be achieved through the social media platforms Instagram and Facebook, to initiate sharing individual and personal use stories of clothing visually.

We decided to use visual methodologies in the form of video diaries that recorded the process and conversations. As this offers all students a confident medium for communication via smart phones, use of film apps and social network. For us as researchers it presents the opportunity to analyse the findings using visual and audio forms. Using these methods also creates pedagogy possibilities to use Schon's theory for students learning, enabling the ability to reflect in action and upon action of the experience.

Methods of communication

On a study conducted with 150 Ghanaian fashion students, it was discovered that 90% depended on external family support for the payment of their fees as they were in fulltime education. Though these students had little disposable income, the study established that over 85% of the students owned a smart mobile phone and had data to correspond worldwide and through social media. Over 90% had a Facebook account and 30% were competent with video conferencing.

As academics, the central underlining view in the research is to promote education and training for the advancement of student's future prospects. It was agreed between both sets of students that communicating through video conferencing would create new knowledge for the Ghanaians and enhance communication skills for the UK students. Skills can be therefore transferred across the globe. The conclusion is a video conversation between six fashion students.

Conclusions

This paper draws attention to current opportunities that do and could exist within education and industry to make a sustainable change globally. Using the current issues and turning these around through conversation and design possibilities. As Walker (2011) argues, the conventions of design that we have become used to, that are linked to mass production, intensive resource use, and disrespectful human relations, need to change. In order to begin developing alternative approaches to our existing production systems and material culture, we need design work that is experimental, probing and iterative. (Cross, 2006) refers to this as designedly ways of thinking. This paper and project continues these lines of thought, bringing research and action into the process of designing. The project is in the early stages of progress and is on – going.

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Routes for extending the lifetime of wind turbines

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Keywords: lifetime extension; wind turbines; environmental impacts; circular economy; lifecycle assessment.

Abstract: Resource depletion, resource efficiency and circular economy are all terms that have gained attention recently. Extension of the product lifetime is one of the key strategies to strengthen the circular economy. Wind turbines produce low carbon energy, but do at the same time contain large amount of materials. To be resource effective getting the most out of the materials is of high concern. The potentials for extending the lifetime of wind turbines are analysed by applying different circular economy initiatives being service/maintenance, reuse/redistribution and remanufacture/ refurbishment.

The performance level of a wind turbine has to be kept on a certain level to make it feasible to continue operate the wind turbine. The different approaches represent ways of doing this and thereby keep the materials in the loop for a longer period of time.

An assessment on the impact of extending the lifetime of a wind turbine shows environmental improvements can be achieved by extending the product lifetime. However, the lifetime of a turbine is also determined by several other factors, and the economic lifetime of the turbines is often shorter than the technical durability.

Extending product lifetimes

Circular economy as a concept has gained attention worldwide. One strategy of the circular economy is prolonging the lifespan of products thus thereby slowing down the throughput of resources in society and reducing the amount of waste.

Back in 1998 von Weizsäcker et al. (p. 70) argued that '*durability is one of the most obvious strategies for reducing waste and increasing material productivity.*'

Increasing material productivity or resource efficiency is on the political agenda, but depletion of resources and downcycling of materials has not been a main focus until recently. In fact, much of the materials are wasted as a result of the way consumption and production has developed (Bakker, et al., 2014). To reduce the throughput of materials and energy demands, Cooper claims that a strategy that goes beyond recycling and includes longer lasting products must be applied (Cooper, 2010).

The circular economy, as presented by Ellen MacArthur Foundation, highlights the 'power of the inner circle' and the 'power of circling longer'. It refers to minimizing the material use by: 1) maintaining and repairing rather than reusing and recycling; and 2) prolonging the life cycles a product. A prolonging of the usage will substitute virgin material inflows (Ellen MacArthur Foundation, 2013).

Cooper highlights that:

'A circular economy is a prerequisite for sustainability but may not be sufficient if resource throughput remains high. … A complementary approach would be to slow down the rate at which raw materials are transformed into products and the products 'used up' (Cooper 2010, p. 13).

Extension of product lifetimes requires support by the business model by maintaining value in the product (Bakker, et al., 2014) or as highlighted by Stahel (2010) that a shift in focus from resource throughput to asset management is needed.

Cooper divides the product lifespans into different categories e.g.:

1. *The technical lifetime* being the maximum period a product has the physical threshold to function.
2. *The replacement or economic lifetime* being the period from initial sale to the point where the owner buys a replacement regardless of the product functioning or not (Cooper, 2010).

Increased product life span is a more efficient use of materials and a slowdown of throughput. The reduction will probably not be offset by increased consumption as the 'resources' put into this is mainly renewable, being man hours for maintenance and repair (Cooper, 2010) (Stahel, 2010). However, some products will require new components and transport of the service technician.

Extending the product lifespan will not necessarily make a positive contribution towards sustainability. If the benefits of product improvements are outcompeted, it may be more favourable to replace it with a more efficient successor. The moment for replacement depends on the specific product and technology development (Bakker, et al., 2014). An industry that has integrated maintenance as part of the business model is the wind industry.

The lifetime of a wind turbine

A modern wind turbine is typically designed to work for approximately 120.000 hours throughout its estimated life span of 20 years (European Wind Energy Association (EWEA), 2014). However, some larger offshore turbines now have a projected lifespan of 25 years.

A wind turbine is a serial system. The reliability of the entire system is the output of individual sub-system reliabilities meaning that the failure rate of the system is the sum of individual sub-system failure rates (Ortegon, et al., 2014).

Specific components within the turbine are subject to more tear and wear. Generally, the moving parts are worn out faster than static parts, and exposed components are worn out faster than shielded components. Blades and gearboxes have historically been considered to wear out the fastest (WMI, 2014).

The actual lifetime of the turbine depends on the quality of all the components of the turbine, their assembly and the environment the turbines are placed within such as onshore, offshore, wind, turbulence, air density, humidity etc. The turbulence will in general be lower at sea as there are no obstacles (WMI, 2014).

The capacity factor

The capacity factor during the lifetime of a wind turbine is essential, when considering extending the lifetime, as it must remain at a certain level to make it feasible to run the wind turbines.

The capacity factor is calculated as:

'the ratio of the amount of electricity actually produced by a turbine or wind farm over a period of a month or a year divided by the amount of output that would have been produced had it operated at full nameplate capacity for the entire period. This is expressed as a percentage, so that reported capacity factors lie between 0 and 100' (Hughes, 2012, p.9).

The capacity factor for wind power has historically been assumed in the range of 30–35 % of the name plate. Some studies have however shown examples of mean values below 21 % (Boccard, 2009), but new wind turbine parks are however often calculated with an expected capacity factor between 37 – 40 % (Siting Specialist, 2015).

Different factors affect the capacity factor. Three better understood are:

1. *Machine availability*: Downtime of the turbines or the electrical infrastructure can affect the output by 4 to 7 % in decline (Staffell & Green, 2013).
2. *Operating efficiency*: Sub-optimal control systems, misaligned components and electrical losses within the farm can reduce the output by 2 % of the turbine (Staffell & Green, 2013).
3. *Wake effects*: Wind farms are affected by power loss as neighbouring turbines increase turbulence and reduce wind speeds. The output can drop in the area of 5 to 15% (Staffell & Green, 2013)

and two less understood are:

1. *Site conditions*: Imperfections in the local environment like e.g. turbulence intensity and terrain slope will impact the output. These are site specific and will vary, but are estimated to reduce output by 2 to 5% plus 1 % per 3% increase in turbulence intensity (Staffell & Green, 2013).
2. *Turbine ageing*: Different factors of decline in output as the turbines age. (Staffell & Green, 2013).

The capacity factor over time

A thorough study on wind turbines in UK and Denmark by Hughes concludes a significant decline in the average capacity factor (adjusted for wind availability) as the turbines ages. It concludes that the capacity factor in UK decline with 0.9 percentage points per year the first 10 years of operation starting at approx. 24 % and falls to 11 % at age 15 (Hughes, 2012).

Another study by Staffell and Green that analyses the same data concludes that the decline with age is 0.45 percentage points per year, which is quite different from Hughes. (Staffell & Green, 2013).They further claim that farms built before 2003 have a decline rate two to three times higher than turbines built after 2003 (Staffell & Green, 2013), which is indicating a more reliable technology today than earlier.

An analysis by McKinsey & Company finds that performance is unrelated to the age of wind parks (and of the manufacturer). However, factors such as e.g. dirty blades can prevent the wind force from being transmitted to the blades and the generator, which results in lower output (McKinsey & Company, 2008).

There are however strategies to maintain a high performance and thereby make a basis for lifetime extension. Lifetime extension can follow different strategies. These are analysed below and the environmental impact of lifetime extension is assessed.

Routes for lifetime extension

The following section will analyse the present approaches of 1) service/maintenance, 2) reuse/redistribute and 3) refurbish/ remanufacture, to maintain a certain level of capacity factor.

Service/Maintenance

A study by Ortegon, Nies and Sutherland present that the number of failures, the downtime and the cost will be drastically reduced with regular maintenance (Ortegon, et al., 2014).

The service concept has been gradually integrated in the business model of the OEMs (Original Equipment Manufacturers) in the wind industry.

Supervisory control and data acquisition (SCADA) systems are integrated parts of modern wind turbines, which makes it possible to remotely monitor information such as electrical and mechanical data, operation and fault status, meteorological data and grid station data constantly. It regulates the active power output of the turbine and is an essential part in keeping the capacity factor as high as possible. Further, turbine condition monitoring systems are now available, which makes it possible to perform precise condition diagnostics based on vibration, which can give an early warning if any components are having problems and thereby reduce maintenance costs and optimize energy output (Siemens Wind Power, 2014).

The diagnostic tools are getting more and more advanced and are able to prevent problems before they occur. The field is developing and lately has a system to monitor the transistor been developed, which detects failures before it overheats, which can prolong the lifetime of the wind turbine (Frandsen, 2014):

The service business of the OEMs has grown rapidly over the last years and has proven to be a good business case for both the OEMs and the wind turbine owners.

Recently, the service concept has been even more sophisticated and presents refurbish or reuse options offered by the different OEMs (see below).

Reuse/Redistribution (new location)

Reuse/redistribution can be a good option, when e.g. a wind turbine reach its economic life at one site (time period with subsidies), but not its technical life.

Several private companies are 'brokers' of this service e.g. Repowering Solutions, Hitwind etc, but also an OEM as Vestas has launched it's 'Wind for Prosperity'-programme in late 2013, which deals with this life extension option on a larger scale (Vestas Wind Systems A/S, 2013).

The 'Wind for Prosperity' aims at *'combatting energy poverty and deploy green technology in developing countries' by committing to source and factory-refurbish a selection of wind turbines that have favourable dimensions for transportation and erection'* (WindforProsperity, 2014).

As the main market for 'Wind for Prosperity' is third-world countries, Vestas mainly focus on 'small' wind turbines (WindforProsperity, 2014). Vestas has teamed up with ABB to deliver wind power to local communities (Wang, 2014).

The business model behind Wind for Prosperity can act as a pilot project for other and larger types of turbines, so technical well-functioning wind turbines can have an 'afterlife' on another location.

Remanufacturing/Refurbishment (same location)

Remanufacturing of wind turbines is another possibility. Interest in refurbishment from an owner perspective can come from permitting e.g. height restrictions on some properties (Dvorak, 2014). Experience with other remanufactured products indicates that when costs of a remanufactured product exceed 70% of a new product, the new product is preferred.

Studies show that the effective age of a remanufactured wind turbine is estimated to additional six years (Ortegon, et al., 2014).

The Spanish wind turbine manufacturer, Gamesa, proposes an 'aging fleet solution' offering a service program that focuses on lifetime extension of wind turbines. The wind turbine life-extension program consists of a series of structural reforms and a monitoring system designed to prolong the useful lives of wind turbines (Gamesa, 2014).

The programme includes both some Gamesa turbines, but also turbines from competitors. The estimation is to add a 10 year life extension. The focus is mainly on <1MW turbines as they are reaching the 20 years design life at the moment, but Gamesa plans to include larger turbines. Gamesa expects the cost to be half of the extra revenue generated by the life extension (Dvorak, 2014). Gamesa is taking part in the European Union-sponsored project, SafeLife-X that seeks to develop effective solutions for minimizing the ageing of industrial infrastructure (Gamesa, 2014).

Other OEMs has also started to look into this side of the business. Examples are:

In May 2014 Vestas introduced their PowerPlus™ programme (Vestas Wind Systems A/S, 2014), which focus is upgrade of existing turbines to increase annual energy output (AEP). The programme offers upgrades within three different areas and depending on the turbine and the number of upgrades, the AEP is estimated to increase by 2.3 % - 6.8 %. It can potentially make it feasible to keep old and smaller turbines running for some extra years (Dvorak, 2014).

General Electric have developed an upgrade on the blades, so their 77m blades can be replaced with 91m, which will increase the swept area by 40% and can boost the AEP by approximately 20 % (Dvorak, 2014).

The routes for lifetime extensions are becoming digitalized by companies like 'Spares in Motion', which just have received the award 'Best Industry Newcomer (Froese, 2015). It acts as a e-trading platform for the services used for lifetime extensions. It reduces the complexity, cost and lead time for these services and thereby does this innovative business model improve the possibility of lifetime extensions.

The different approaches all present possible ways to optimize the turbine during its lifetime and thereby making it attractive to extend the lifetime of the turbine. The larger the turbine is, the more revenue is created by the upgrade.

The wind turbine industry is still in a developing phase, which complicates the access to spare parts as it changes over time and from producer to producer. A standardisation of some components across the industry could help ease the maintenance and remanufacture possibilities.

The environmental impact of lifetime extension

The best approach from an environmental perspective is not straightforward. The routes for lifetime extensions have to be done on an individual basis as different turbines on a wind farm see different types of loading, which leave them at different stages after e.g. 15 or 20 years (Dvorak, 2014).

In 2012, Kenetech chose to repower 235 turbines after an analysis, whereas EDP Renewables reviewed their 153 wind parks and chose to extend the project life of the parks from 20 to 25 years, which highlights the different strategies (Houston & Marsh, 2014).

An assessment of the environmental impact on extending the lifetime can be seen below in Table 1. The calculations is based on a life cycle assessment for a 3.2MW onshore wind power plant by Siemens Wind Power, and the data behind the lifetime calculations is provided by Siemens Wind Power.

The assessment of the contribution to global warming shows that the operation and maintenance impact is small. An extended lifetime will have a positive impact on the carbon footprint and the amount of times the energy is paid back will increase significantly.

Lifetime	10 years	15 years	20 years	25 years	30 years
kg CO2/MWh	8.7	5.8	4.4	3.5	2.8
Times energy is paid back	29	43	57	72	86

Table 1. kg CO2 per MWH and times the energy is paid back for different lifetimes of wind turbines.

Conclusion

The way of doing business is changed by moving away from traditional 'take, make and dispose' pattern towards focusing on product durability by integrating asset management. Specifically, it becomes possible for the manufacturer to add value through the lifetime of the product and opens up new business possibilities.

Different studies show as indicated different results regarding performance over age for wind turbines, but it is possible to maintain a high performance and even upgrade the wind turbine over time. In the case of wind turbines different routes of asset management are operational to obtain a long product life being 1) service/maintenance 2) reuse/redistribution or 3) refurbish/remanufacture. The options include different management strategies and the addition of non-renewable resources differs, but the gain from extending the lifetime will often outcompete the added energy and materials.

The OEMs have entered the business of service and are getting more and more sophisticated and have at this stage shown different potentials of prolonging the lifetime and thereby improving environmentally and economically.

The lifecycle assessment of a scenario with regular service/maintenance and replacement of some components shows that the environmental benefit from prolonging the lifetime is significant. Environmentally, it is worth maintaining the wind turbine to reach its technical lifetime, the question is how to make the economic incentives support this.

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Handled with care: repair and share as waste management strategies and community sustaining practices

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Keywords: repair; share; waste management strategies; design; community building.

Abstract: Waste is progressively prevailing but persistently ignored in conditions of abundance and material comfort; unquestionably, that which the modern discourse of living standards especially in developed societies has generated, is an inability to confront the consequences of an ever-accelerating product redundancy economy. The necessity for the recognition of this condition in the context of a Western city (Brisbane, Australia) led to the design and realisation of a research project titled 'Handled With Care: Developing The Paradigm Of A Culture Of Repair And Share'. The aim of this project was to create possibilities of engaging Brisbane's residents in dematerialising practices such as repairing and sharing via giving them access to an up-to-date inventory of the existing businesses of repair and organisations of share in central Brisbane. By identifying not only longevity and emotional durability but also dematerialisation as waste management strategies its goal was to encourage people to re-evaluate the use of their material belongings and re-direct their consumption routines.

For the realisation of the project the descriptive case study method was adopted and for its purposes, an online map of the 'repair and share' geography of central Brisbane was created, which was embedded on a digital platform (website) and an Application (App).

In conclusion, the findings of this project revealed an existing community of repairers and sharers who were willing to be included in the project and provide valuable material, and exposed current repairing and sharing trends as well as the neighbourhoods where these phenomena have an active presence.

Introduction

The linkage between waste and unsustainability was detected as early as individual researchers, governmental bodies and world commissions started to identify the consequences of global development and three centuries of industrial activity. In 1972 the book 'Limits to Growth', provided estimations in regard to where the development of the material economy could lead and warned that the combination of emissions and the exhaustion of natural resources could have detrimental effects on humanity. In 2004, an updated version of the book demonstrated that, despite international and governmental environmental policies and Westerners' habitual changes, humanity had exceeded nature's limits and environmental waste was overtaking the planet while natural resources were reaching alarmingly low levels (Meadows et al., 2004). A year before, John Gertsakis and Helen Lewis, in their discussion paper on waste management hierarchy (2003), made the same statement and additionally stressed the importance of promoting dematerialisation as a strategy to reduce waste. Dematerialisation can be defined in a number of ways; in relation to waste, Herman et al. (1989, p. 51) addressed it as '...the change in the amount of waste generated per unit of industrial products'. For the purposes of this paper dematerialisation will refer to a practice that requires deliberation on and awareness of materiality's sustaining role for all forms of life (Kalantidou, 2015).

The case study

Background

Despite designers (Moles & Jacobus, 1988; Poole & Simon, 1997; Tonkinwise, 2004), scientists (Von Weizsäcker, 1998) and economists (Ayres & Simonis, 1994; Cogoy, 2004) acknowledging dematerialisation as a waste management practice and the shift from products to services as an approach that could minimise consumption and production, recycling and up-cycling continue to dominate the sustainability discourse as the main practices of 'damage-control'. And while dematerialisation literature has indicated that people should adopt a 'maintenance mentality' (Moles & Jacobus, 1988, p.26), replace products with services and use of networks (Poole & Simon, 1997), embrace 'using instead of owning' and 'repairing and servicing' (Cogoy, 2004 p.169-70), still, there is not enough research evidence to support a structural and habitual change towards that direction. Accordingly, re-coding the 'outmoded' and the 'used' as non-redundant and sharing what is temporarily not needed are not even part of the 'transition' discussion that currently dominates architectural conferences and design round tables.

The limited number of publications that supports repair and re-use as waste management strategies identifies the invisibility of relevant practices (Graham & Thrift, 2007; Edgerton, 2008), points out how disposal and replacement are systemically reinforced (for instance, it is cheaper to replace broken goods than try to fix them in advanced economies) (Edgerton, 2008) and highlights the significance of cognitive and practical skills that maintenance entails (Sennet, 2008; Sassen cited in Amin, 2013). Furthermore, some researchers provide successful examples that demonstrate how repair and share work as waste management practices in underdeveloped countries such as India (Doron, 2012) and Egypt (Hofmann, 1986). In these contexts, fixing and sharing are part of an informal network driven by conditions of poverty and lack of means and play a key-role in everyday living; second hand clothes and repairing a broken phone are taken for granted not out of choice but out of necessity. Without being conscious acts of sustainable behaviour they lead to a great deal of elimination of waste by people using up goods. Their relation to materiality comes out of real, non-fabricated needs, and it is of great importance for this condition to arrive in wealthier countries.

From a Westernised perspective, the examples found in literature, which are indirectly related to repair such as Emotionally Durable Design (Chapman, 2005; Van Hinte, 1997), the rise of Do It Yourself (DIY) and the commodification of fixing (for example, the availability of fixing mouldable glue Sugru in ten different colours) follow a more instrumental approach, greatly impacted by the post-industrial, capitalist model of living. Despite the fact that they are successfully putting an anti-consumerist front, by promoting an uncritical attachment to artefacts they encourage a mentality not rooted in understanding the degree of which life is dependent on material resources. They remain reluctant to go beyond tokenism and put their efforts into stripping away sign value from things and as a result, people hold on to the old under the banner of product 'longevity', whilst acquiring the new.

Aim

The issue of 'visibility' as addressed by researchers and theorists that have negotiated issues of repair and re-use inspired the mapping of the culture of repair and share in Brisbane, Australia. A research project titled 'Handled with Care: Developing the paradigm of a culture of repair and share [1]', was conducted so as to explore a modern, urbanised milieu (central suburbs of Brisbane) in order to discover the number and kinds of repair and share facilities and depict them on a map incorporated in a custom-made digital platform and an application (App). Via the digital platform the project aimed to introduce to Brisbane's audiences an alternative option to consumerism by making more accessible information on businesses and organisations, which provide services of repair and share. Finally, by integrating an experiential forum in the digital platform the aspiration was to invite an exchange of information, knowledge, skills and anecdotes so as to make people familiar with practices that contribute to the reduction of waste (Kalantidou, 2015).

Method

The descriptive case study (Yin, 2014) was chosen as the method for the assessment of the facilities of repair and share and its design was based on the conceptual framework that was generated from a literature review.
Scholarly articles, published studies, books and other sources on topics such as dematerialisation, waste management, repair and maintenance, user's experience and design for behavioural change, informal

[1]This project was funded by Griffith University as part of the New Researcher Grant Scheme 2014.

learning, social practices for sustainability and sustainable policies were reviewed, as well as information relevant to existing similar activities that have been taking place in various places around the globe (Fixers collective, New York - Repair cafes, Netherlands, UK, Belgium, India - Repair parties, San Francisco) and in Australia (Tool and Toy libraries, Brisbane, Sydney, Melbourne - The Bower re-use and repair centre, Sydney). Case studies from the retail sector (for example, 'Nudie jeans' repair policy) were also examined.

The conceptual framework that was generated from the literature review enabled the establishment of a protocol prior to the data collection that included an outline of the project, field processes, research questions formed through the reviewed readings and cases, and a description of the final report's format. The main questions were related to what kind of facilities exist, how many, where, with which particular characteristics and if there were any obstacles inhibiting the development of a culture of repair and share. During this preliminary phase, twenty-five suburbs were designated as the physical locations of the study (Central Business District of Brisbane according to the University of Queensland and zone one and two according to Translink[2]).

The prospective participant facilities were identified via yellow pages, search engines, blogs and articles related to repair and share. The repair of artefacts and the provision of sharing services defined the criteria for their identification. In regards to repair, the artefacts were divided into three groups: electronics, furniture and clothing/shoes.

Documents, interviews and photographs of artefacts were collected as sources of evidence during the field study, which took place between September and November of 2014. The interviews were structured and had the form of questionnaires with open-ended questions that were generated from the literature review. Prior to the field visits, the prospective participants were contacted via phone-call and/or email and all the visits were prescheduled. The field visits were conducted by predefined pairs of volunteer researchers, who provided consent forms and information sheets to the participants, carried out the interviews, collected relevant documents (price lists, policies, etc.) and took photos of the means of repair and the physical locations. The interviews were recorded and the researchers kept diaries with personal observations. The collection of data process was realised after ethical clearance was acquired (Protocol number: QCA/06/14/HREC) (Kalantidou, 2015).

Findings

The facilities that were identified through the aforementioned mediums (Table 1) were 101 from which five did not match the criteria (repair or sharing facility within the studied area), 16 couldn't be reached (were closed down or changed location and details), one practice allowed the researchers to take photos but did not agree on participating in the study and 40 facilities did not want to be part of the online platform (either because of schedule conflicts or for reasons that were not mentioned to the researchers). From the 101 identified facilities 39 agreed to participate in the study and appear on the online map from which 13 (33%) were clothing/shoes repair facilities, 8 (20.51%) furniture repair facilities, 6 (15.38%) electronics repair facilities and 12 (30.77%) sharing facilities.

Table 2 provides a description of the population demographics [3] concerning the investigated groupings (repair and sharing facilities).

[2] Sources: University of Queensland (http://www.uq.edu.au/student-services/sites/default/files/St%20Lucia%20and%20%20inner%20city%20suburbs.pdf)

and Translink (http://translink.com.au/sites/default/files/assets/resources/travel-information/network-information/maps/130401_inner-brisbane-zones.jpg)

[3] According to data sourced from the Australian Bureau of Statistics http://www.censusdata.abs.gov.au/census_services/getproduct/census/2011/quickstat/3GBRI?opendocument&navpos=220

ALL PRACTICES	Repair (clothing /shoes)	%	Repair (furniture)	%	Repair (electro-nics)	%	Share	%	TOTAL	%
Included										
Participate	13	33.33%	8	20.51%	6	15.38%	12	30.77%	39	**38.61%**
Not included										
Did not participate	13	32.50%	14	35%	9	22.50%	4	10%	40	**39.60%**
Non existent	5	31.25%	10	62.50%	1	6.25%		0	16	**15.84%**
Non included (didn't match the criteria)	1	20%	1	20%	2	40%	1	20%	5	**4.95%**
Photos (no interview)	1	100%		0		0		0	1	**0.99%**
Total	**33**		**33**		**18**		**17**		**101**	**100%**

Table 1. Number of facilities and percentages per kind (Kalantidou, 2015)

In regard to the participant facilities, the most interesting findings are in relation to furniture repair facilities. From the investigated suburbs, 33.72% of their inhabitants have access to participant and non-participant furniture repair facilities. The data shows that their weighted average of household income is lower than the median and a relatively low percentage of residents hold a university education. Nonetheless, the unemployment rate is average. The income level of investigated suburbs' inhabitants who have access to the participant furniture repair facilities (15.94%) is inferior to the rest of the groupings and the same goes for their educational status but not for the degree of unemployment, which appears to be below the median. On the contrary, the furniture repair facilities that did not agree to participate in the study are located in areas where the weighted average of household income is comparatively the highest, the percentages of residents that have acquired tertiary education are above average and the unemployment rate is among the highest.

Noteworthy were the data generated from the 'electronics' grouping. 44% of the residents living in the suburbs included in the study who can repair their electronic devices to a facility nearby, is comparatively among the youngest, the richest and the most well-educated; additionally, they are affected by average rates of unemployment. From them, 15.09%, with income close to the median and a high rate of university degrees, lives within the reach of the participant electronics repair facilities that are located in areas of low unemployment. The relatively high number of electronics repair facilities that chose not to participate in the study is located in suburbs where residents have high income and tertiary education, are of age below the median and are impacted by an average rate of unemployment.

There were a lot of similarities between the populations of the participant and non-participant clothing/shoes repair facilities except the fact that the residents of the suburbs that agreed to be part of the study have significantly higher incomes than the ones that reside in suburbs with non-included facilities.

Finally, from the sharing facilities, the participant ones correspond to 32.7% of the total facilities, a percentage, which is significantly higher than the 12.1% of the non-participant facilities. What is remarkable is that the income of the residents living in the suburbs of the non-participant sharing facilities are not as high as that of the ones that live in the suburbs with facilities that participated in the study.

Demographics	Population Reach Percentage Correspondence	Weighted Average of household income medians	Weighted average of tertiary education percentage medians	Weighted average of age medians	Weighted average of unemployment medians
Participant repair practices	45.02%	1550	33.45%	32.3	6
Participant sharing practices	32.70%	1548	34.70%	32.3	6
Participant furniture practices	15.96%	1396	26.45%	35.7	5.71
Participant clothing/shoes practices	35.29%	1614	35.80%	31.8	6.3
Participant electronic practices	15.09%	1558	35.40%	31.3	5.48
Non participant repair practices	66.79%	1597	35.50%	31.2	6.34
Non participant sharing practices	12.10%	1361	35.20%	31.2	6
Non participant furniture practices	28.46%	1644	30.61%	32	6.48
Non participant clothing/shoes practices	33.17%	1421	36.50%	31	6.4
Non participant electronic practices	38.70%	1649	37.30%	30.8	6.19
Total repair practices	82.20%	1580	34.79%	31.59	6.21

Table 2. Population demographics in regards to the investigated groupings.

Besides the population demographics, the method of descriptive statistics was also used for the depiction of the evidence collected from the interviews. Categorical aggregation [1] was adopted as the strategy for the content analysis of the answers, the findings of which will not be presented in this paper.

The information generated from the questionnaires used for the interviews (Table 3) showed that half of the sharing facilities operate on a fee/membership basis whereas half do not charge their members. Almost all of them hold community activities (91.67%) and a notable number runs educational workshops (83.33%). Impressively, all of them follow social responsibility practices (concession etc.) and 83.33% re-uses underused space.

The repair clothing/shoes facilities (Table 4) follow in great majority waste management practices (84.60%), and almost all charge for their services (84.6%). A 69.20% of them offer apprentices and 46.15% conducts educational workshops. The repairers are mostly people who were taught their craft within the family or had exposure to traditional knowledge (69.20%). In addition, social responsibility practices are equally adopted and not adopted by the facilities (46.15% respectively).

[1] A detailed discussion on the findings of the categorical aggregation can be found in ‘Share + repair = care. Recoding reuse and establishing dematerialization practices by design’ (Kalantidou, 2015).

SHARING	YES	%	NO	%	N/A	%	TOTAL	%
Membership/rent fee	6	50%	6	50%		0	12	100%
Community activities	11	91.67%	1	8.33%		0	12	100%
Educational workshops	10	83.33%	2	16.67%		0	12	100%
Social responsibility practices (Concession etc.)	12	100%		0		0	12	100%
Re-use of underused space	10	83.33%		0	2	16.67%	12	100%

Table 3. Sharing facilities-number of responses and percentages.

REPAIR (CLOTHING /SHOES)	YES	%	NO	%	N/A	%	TOTAL	%
Waste management practices	11	84.60%	1	7.60%	1	7.60%	13	**100%**
Fees for services	11	84.6	2	15.40%			13	**100%**
Apprenticeships	9	69.20%	4	30.80%			13	**100%**
Educational workshops	6	46.15%	7	53.85%			13	**100%**
Informal learning/traditional knowledge	9	69.20%	4	30.80%			13	**100%**
Social responsibility practices (Concession etc.)	6	46.15%	6	46.15%	1		13	**100%**

Table 4. Repair (clothing/shoes)-number of responses and percentages

The repair furniture facilities (table 5) demonstrate a common, positive approach towards waste management practices (100%) and they all receive a fee for their services. Surprisingly, only one accepts apprentices (12.50%) and in respect to informal learning and traditional knowledge 62.50% of the participants has been trained under these circumstances. A small percentage, in comparison to other repair facilities, has established social responsibility practices (37.50%).

REPAIR (FURNITURE)	YES	%	NO	%	TOTAL	%
Waste management practices	8	100%		0	8	100%
Fees for services	8	100%		0	8	100%
Apprenticeships	1	12.50%	7	87.50%	8	100%
Informal learning/traditional knowledge	5	62.50%	3	37.50%	8	100%
Social responsibility practices (Concession etc.)	3	37.50%	5	62.50%	8	100%

Table 5. Repair (furniture)-number of responses and percentages.

REPAIR (ELECTRONICS)	YES	%	NO	%	TOTAL	%
Waste management practices	5	83.33%	1	16.67%	6	100%
Fees for services	5	83.33%	1	16.67%	6	100%
Apprenticeships	2	33.33%	4	66.67%	6	100%
Social responsibility practices (Concession etc.)	2	33.33%	4	66.67%	6	100%

Table 6. Repair (electronics)-number of responses and percentages

Waste management practices are part of the activities of the electronics repair facilities (83.33%) (Table 6). For most of them fee is required (83.33%) and a minority trains unskilled people (33.33%). The same percentage depicts the facilities that follow social responsibility practices.

Discussion

The analysis of the collected data brought to surface a culture of repair and share that demonstrates characteristics of anti-wasteful behaviour, community-oriented mentality and appreciation of practical skills. Notwithstanding it has not found a predominant place within society yet, it holds the potential to become a leading apparatus towards extending the life of artefacts via maintenance and reuse. The fact that a number of repair facilities chose not to appear on the online platform [1] and App [2] discloses an unawareness of the value of their skilling attributes and contribution to minimising disposal. From a different perspective, the sharing facilities provide an example of action based on understanding the profound consequences of wasteful conduct. As a result, a high percentage of sharing facilities were willing to appear on the digital map, a stance that depicts a desire to grow and to welcome more people to a mode of living grounded in object exchange and redeployment.

Likewise, the population demographics' analysis exposed a thought-provoking suburb distribution of participant and non-participant facilities that indicates a mixed perception of the significations of repair and share. To clarify, the percentage of participant sharing facilities

[1] www.handledwithcare.org.au

[2] https://itunes.apple.com/us/app/handled-with-care/id976876953?ls=1&mt=8

located in suburbs where people of high incomes and higher education reside, suggests that sharing is not seen as a practice for the disadvantaged. Nonetheless, in similar conditions of financial and educational status, electronics and furniture repair facilities appeared reluctant to be identified as part of the culture of repair and share.

As has been noted in this paper, its intention was to describe a phenomenon and present as many of its facets as possible. The limited resources, time and number of the investigated facilities as well as the non-explanatory character of the research project correspondingly led to indicative suggestions and comments, and not solid conclusions. It generated though a cartographic representation that illustrates the existence of the facilities that were willing to become visible through the custom-made digital mediums of this study. This opens the way to expand the discovering and mapping of cultures of repair and share outside central Brisbane, and develop the project further by initiating skilling workshops and sharing events.

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Hardware hopes: examining emotional connections to computers through creative story telling

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Keywords: attachment, keeping behaviours, value, emotion, technology, empowerment.

Abstract: Hardware Hopes is a qualitative research project initiated to explore the personal and emotional side of our relationships with computing devices, by inviting people to tell the stories of the devices they own (e.g. laptops, desktop computers, smartphones, tablets), and asking them to consider how they feel about them. Through analysis of the collected stories I am investigating the ways in which emotion is present, or absent, in our relationships to computing hardware.

Recent work in HCI and design establishes the case for designing longer lifespans into computing devices, to address the problem of increasing waste produced by the fast consumption cycles associated with electronic products. These researchers advocate finding new ways of relating to, and caring for, our devices. The research documented in this paper attempts to understand the emotional and material factors that affect the longevity of people's personal relationships with computing devices. Computer obsolescence and replacement is often reported and marketed as a necessary by product of technological progress, but the reality of deciding whether a personal computing device should be kept or disposed of is personal and idiosyncratic, and messier than it may at first seem. Understanding the factors that influence whether a device is kept can tell us about the lifespan and obsolescence of computing devices.

Introduction

Hardware Hopes is a qualitative research project initiated to explore the personal and emotional side of our relationships with computing devices, by inviting people to tell the stories of the devices they own (e.g. laptops, desktop computers, smartphones, tablets), and asking them to consider how they feel about them. Through analysis of the collected stories I am investigating the ways in which emotion is present, or absent, in our relationships to computing hardware.

Recent work in HCI and design establishes the case for designing longer lifespans into computing devices, to address the problem of increasing waste produced by the fast consumption cycles associated with electronic products. These researchers advocate finding new ways of relating to, and caring for, our devices. The research documented in this paper attempts to understand the emotional and material factors that affect the longevity of people's personal relationships with computing devices. Computer obsolescence and replacement is often reported and marketed as a necessary by product of technological progress, but the reality of deciding whether a personal computing device should be kept or disposed of is personal and idiosyncratic, and messier than it may at first seem. Understanding the factors that influence whether a device is kept can tell us about the lifespan and obsolescence of computing devices. Key research questions include:

- What are the material and emotional factors that influence the longevity of a personal computing device?
- How do we keep personal computing devices when our relationships with them start to wind down and end?
- Can individual items of hardware build up personal meaning?
- How could design support more authentic, caring and active relationships with devices?

The stories were collected through two events in 2014, with participants from Access open digital art space, Sheffield, and visitors to Manchester Mini Maker Faire. This paper describes the creative methods for collecting the stories, and presents the themes arising from the data analysis. The research builds on earlier research I have undertaken taking a creative, storytelling approach to examining keeping behaviours related to personal possessions.

Contextual review

E-waste: an accelerating problem

The explosive growth of the electronic waste stream (including computers, mobile phones, TVs, electronic toys, and other household appliances) is widely acknowledged as a serious global problem (Vidal, J. in Observer newspaper, 2013). A paper by Step Project (United Nations University, 2014) states that global e-waste volume placed on the market was 57.4 million tons in 2010, and set to rise to 75 million tonnes by 2015. The technical and material complexity of electronic products, and the relatively recent development of the e-waste stream, mean that the appropriate infrastructure for disassembly and reuse is not clearly defined or well developed (Gabrys, 2013). Many products are informally processed in developing countries, where the infrastructure for safely processing e-waste is lacking. This has a serious negative impact on environment and health (Park, 2012).

Dominant narratives of obsolescence The production and consumption of electronics is tied up with ideas of technological progress. In 1965 Moore predicted that the number of transistors on integrated circuits would double every 18 to 24 months, doubling processing speed. Gabrys (2013, p30) states, “This law has become a nearly inviolable principle for the rate of electronics advancement.” The increasing miniaturization of microchips, the pace of technological change, and the relationship of consumption to economic growth means that electronics have become part of a dominant culture of replacement and disposability.

Product lifetime extension

Research in design and HCI establishes a need to design long or multiple lifetimes into products, in order to address the problems associated with overconsumption and waste. This need is confirmed by Defra, who commissioned research into consumer attitudes and behaviours associated with product lifetime (Brook Lyndhurst, 2011). Recent design research identifies a need to understand what motivates people to keep and care for products for prolonged periods (e.g. Chapman, 2005; Mugge et al., 2010; Niinimäki & Koskinen, 2011; Schifferstein & Zwartkruis-Pelgrim, 2008). This research often seeks to identify the characteristics of a strong user-product attachment. HCI researchers Golsteijn et al. (2012) and Odom et al. (2009) have explored attachment to digital and physical possessions, while Gerber (2011) examines the breakdown of peoples’ relationships to technology. There are also calls to design for multiple lifespans in electronic products, and for electronic devices that build up meaning (Odom, 2012). My intention is to shift the focus from product attachment to more deeply investigate how material and emotional engagement are linked, and how they inform a person’s relationship with their device.

Framing the ownership of a device as a relationship is a useful way of understanding a person’s emotional interaction with it. Chapman (2005) talks about the ownership of a product as a relationship that can break down when a user ‘grows out’ of the product, and outside academia the Restart project [Restart Project, 2015] frames the repair of electronic devices in the context of users’ relationships with them. What happens when a user’s relationship to their hardware starts to change? What factors prolong a relationship with a product that is technologically obsolete?

End of life ambiguity

There is ambiguity around what constitutes end-of-life for electronic products; for example it could be the failure of a single component that is the trigger, or the acquisition of new software. Devices are often working, or partially working, when they are discarded (van Nes, 2003 cited in Park, 2012), and it is relatively unusual for a personal electronic device to become obsolete because it is broken beyond repair (Cooper, 2004). This raises questions about how users deal with this ambiguity, when making decisions about whether a device is obsolete. Park (2012) and Gabrys (2013) both draw attention to the apparent stockpiling of devices such as unused mobile phones and computers in peoples’ homes. There is a need to understand the personal, social factors that influence this period of time when a user’s relationship with a device winds down and ends, and to find out how users deviate from expected patterns of keeping and discarding. The influence of consumer expectations on product end–of–life is studied by Cooper (2004) and Brook Lyndhurst (2001). Both studies acknowledge that there is little consistency in consumers' attitudes to product lifespan. Brook Lyndhurst found that products consumers expect to be 'up to date' (including electronic products) are closely related to the "status, belonging and identity of participants", and are only expected to last reliably for short periods. Both studies identified participants' frustration with products that break before the expected end–of–life (Brook Lyndhurst, 2001), and a sense of lack of personal control over the short lifespan of household appliances including computers and mobile phones (Cooper, 2004). Consumers are not motivated to prolong product lifespans out of concern for the environment, and Brook Lyndhurst found that participants were unlikely to take responsibility for prolonging product life spans.

Dematerialisation and material artefacts

Gabrys (2013) has responded to the growing problems of e-waste by seeking to understand the social and material factors that influence the 'ecology' of digital products. She draws attention to the 'dematerialisation' that has accompanied the development of the digital world. She describes the screen as a site of virtuality; a portal for accessing and interacting with the digital world. What we do and create here is virtual, immaterial. We are distanced from the origins and destiny of our material; digital devices and our relationships with them are fleeting. There is a contradiction in the permanence of the material artefact versus its relative, intended transience. Do we have an alienated relationship to the physical, material devices that make digital interaction possible? Are they mere portals, and a means to an end (interacting with the digital world)?

Method and analysis

The data for this study was collected through two events; a two day exhibition event at Manchester Mini Maker Faire (July 2014) and an artist's residency at Access Space, an open access digital arts space in Sheffield (April – July 2014). Through these events I invited people to tell me about the devices they own, and how they use, keep and feel about them. 58 interviews were collected, ranging in length from approximately 2 minutes, to deeper interviews of over 40 minutes. The devices reported on were mostly, although not exclusively, computing devices: desktop computers, laptops, smart phones and tablets. The quantity of interviews from different sources meant that there is a broad spread of themes emerging from the data. The interviews were deliberately kept open in order to allow unexpected themes to rise up.

Access Space residency

Access Space is an open digital arts lab in Sheffield, South Yorkshire. I collected 22 interviews during the residency, ranging in length from 2 to approximately 40 minutes. The Access Space community includes artists and makers engaged in digital production, as well as socially excluded and unemployed people. The only condition for participation in Access Space is that you are prepared to be an active participant. Part of the ethos is the empowerment of community members through learning how to use technology, e.g. building computers, or learning to use Linux open source software (this ethos is explored in detail by Corbett (2014)). Community members tended to have politically aware, critical attitudes to owning and using digital devices, particularly computers. Over the course of the residency I got to know Access Space members, and I invited individuals to participate in open-ended interviews about a device that they owned. I focused on whether they felt any sort of attachment to their device, when they acquired it, whether it had replaced any other devices, whether they kept any older devices at home, and how they used it. I also asked them about their level of expertise in relation to computing and computers. The participants often had an active and knowledgeable relationship with their devices – a 'technophilic' approach. This community of often-critical users is interesting because they are motivated to challenge expectations of use and ownership, and so suggest a picture of how user-device relationships could be conceived differently.

Manchester Mini Maker Faire

The 2-day event at Manchester Maker Faire was structured differently, as a small exhibition of devices, photographs, stories and quotes, for visitors to view. On entering the exhibition they also encountered posters asking "Feel attached to your tablet?", "Frustrated with your laptop?", encouraging them to consider emotions they might have experienced in relation to their

devices. I collected 35 interviews during the event. The interviews tended to be short (on average 3 minutes 40 seconds). It should be noted that participants were largely self-selecting, as they responded to the material they encountered in the exhibition. The people attending the faire and participating in Hardware Hopes included some with active relationships to their devices – e.g. people who upgraded their own devices, or were engaged in hacking and making.
Considering the role of emotion in their relationships to computing devices appeared counter-intuitive to the vast majority of participants. It was overwhelmingly the case that people instinctively reported on the use value of their devices, e.g. how they used it, how well it fulfilled their needs, and technical specification.

Story Telling
This study is part of a larger body of ongoing research, in which I frame interviews in the context of storytelling, as a way of getting at how people experience their possessions. Some of the interviews collected during Hardware Hopes can be understood as stories – a sequence of events, reflections or memories. Open-ended interviews about individuals' possessions are a means of documenting personal stories, as a way of eliciting the emotional value and meaning of the devices. The stories consist of alternative, personal narratives that challenge the dominant marketing narratives that shape our expectations of digital devices.

Method of analysis
The collected stories were catalogued and transcribed, and a two-stage coding exercise used to identify patterns and themes in the collected material. The first stage sought to identify where discussion of emotion emerged in the stories, and the reasons participants gave for keeping their device. In the second stage these findings were grouped to develop the themes arising from the data.

Limitations
Although the research was undertaken in specific communities, a diverse range of attitudes and individual scenarios came through in the interviews. As might be expected, some participants had more active and satisfactory relationships to their devices, but in both events there were participants who did not have specialist knowledge about digital technology.
In the case of the short Manchester Maker Faire interviews, the method as a form of story collecting partially failed, as many participants reported on their devices as consumers, focusing instinctively on the features and functions, rather than considering their emotional experience of them. This is interesting in itself, as it can tell us something about the way we expect computers to perform, and the kind of relationship we expect to have with them.

The short length of the Manchester Maker Faire interviews meant we received a breadth of responses and themes arising, but it made accessing the emotional aspects of owning and using devices difficult, as it was not instinctive for participants to think of their devices in this way.

Findings
Considering the role of emotion in their relationships to computing devices appeared counter-intuitive to the vast majority of participants. It was overwhelmingly the case that people instinctively reported on the use value of their devices, e.g. how they used it, how well it fulfilled their needs, and technical specification. It was implicit in many interviews that computers are useful tools that are expected to fulfil users' needs, and are a vehicle for accessing digital data. Participants tended not to consider their devices in terms of their experience of them as material artefacts.

Emotions reported
In the few cases where an emotional attachment was reported (7 cases), the devices were either associated with important memories (2 smart-phones, a 1970s Polaroid camera and a Morris Minor car), or an appreciation of the aesthetic qualities of the device (a blueberry iMac), or the capacity for the device to help them realise their desires (2 phones). The majority of these contributors (6) appeared to value the individual device, although one person said they would happily replace the device, indicating that that their attachment is transferable.

A greater range (19) of negative feelings in response to a device were reported. These included frustration with outside forces (e.g. the companies providing the operating systems) that are mediated by the device and which exert some control over how the device is used. This frustration was also often accompanied by a sense of vulnerability, related to either the unreliability of the device or the perceived power and control of outside forces. Some participants expressed a sense of helplessness in relation to the device malfunctioning, or recalled fear or nervousness associated with opening up a device and attempting to repair or upgrade it (6: 3 desktops, 2 laptops and a 3D printer). In some cases this frustration or sense of helplessness was connected to a lack of knowledge of how the device works. Some participants sought visible 'clues' by examining the device, or sought help from outside agencies.

Overcoming an obstacle leading to new learning

These negative experiences interrupted the user-device relationships, by presenting a barrier or obstacle to the user. In these cases the device became a conscious focus of attention. It is at key points like this that the relationship can be threatened, but that also present an opportunity to strengthen the relationship. For example, there are 5 instances where the user's efforts to overcome the obstacle lead to new understanding, and a transition to a more empowered relationship. One participant decided to upgrade his desktop PC's RAM card himself. When he tried to insert the card, he put it in place and switched on the computer. The computer beeped and a red light flashed, and he immediately feared he had done something wrong and damaged it in some way. He sought expert help at Access Space, and discovered that he had been cautious and hadn't pushed the RAM card into its slot with enough force. Once he had taken the risk of engaging with the material components of his computer, and overcome the problem, he was able to move on to further adjustments and upgrades.

Subverting dominant ways of owning and using devices

In 6 cases participants actively addressed the failure of digital commodities as intrusive or alienable possessions, by consciously resisting the dominant forms of use and ownership that are marketed and expected. They made efforts to overcome the anonymity of mass-produced devices, or to address the power-relations mediated by the device (the perceived control of companies distributing soft- and hardware over how we live and work). These appeared to be more empowered users with more active relationships to their devices. One participant described how she resisted acquiring a smart phone, and carried her "stupid" phone around her neck, displayed on a piece of coloured fabric. Another described how he continually upgraded his laptop including RAM, power packs, hinges and software, in order to resist replacement culture. He also personalised his laptop with stickers, consciously subverting the image of a 'man with laptop'.

Devices in Purgatory

Other participants reported on devices that were no longer regularly used, but that they still kept (15). These are devices that are kept in 'Purgatory', awaiting a new opportunity for use, or until it becomes clear that they are sufficiently devalued enough to dispose of. 7 of these were kept as they hadn't exhausted their usefulness, were potentially usable, or where partially working and used as backup for another device. These included 2 instances of keeping devices that could read outdated storage, so that old data and memories could still be accessed. 2 cases were broken devices that had been kept, but not as a result of a conscious decision – they simply hadn't been thrown away. 5 participants kept devices that either evoked memories, or contained data that evoked memories. There was often confusion about whether the device was obsolete, and whether it was possible to access the data.

Prolonging the life span of a device

A small number (5) of 'expert users' with technical knowledge and experience continually upgraded and repaired their devices themselves, and therefore continually extended the lifetime of the device. They were motivated by the process of engaging with the technology and using their expertise, or to prolong the device's useful lifespan.

Emotional identity

There are two small clusters of cases where the ownership of a device (usually a desk– or laptop) has allowed participants to realise their identities. The first group (5) have bought devices that hold promise and the potential for how they might work or communicate in the future. This is reflected in how the devices look, and the functions they have e.g. slim, lightweight, powerful, portable. The second group (4) are usually expert users who continually maintain or repair their devices, and through this support family members. For example, one participant has continually upgraded his desktop PC (used primarily for gaming) since 1997. When he takes older components out, he keeps them in boxes, and uses them to upgrade his mother's computer. He also sometimes involves his son in taking apart components, as a learning exercise. So through his physical maintenance of the device he expresses care for family members, and cultivates his relationships with them. It should be noted that desktop PCs are modular and allow for continuous upgrading. So as an individual artefact the desktop doesn't hold an emotional bond, but there is an emotional aspect to owning or physically interacting with it. It is part of an emotional mechanism for realising individual identity.

Conclusions

The collected data builds up a picture of alienable material artefacts that are valued for their use potential and for their capacity to enable people to work and communicate. The research identifies 6 types of owning and keeping that influence the lifespan of devices, and that deviate from straightforward patterns of purchase-use-discard-replace. Digital devices tend to resist long-term emotional attachment and we generally do not expect to keep and use them for long periods. However the study identifies behaviours that contradict expectations of use, and emotion arises in our relationships to devices in ways we might not expect.

Some participants frustrating barriers to their positive engagement with their devices, and sought visible ‘clues’ from their devices in order to solve problems. Others persisted in finding ways of resolving problems, such as breakages or upgrades, leading to new learning, and to a more informed and empowered relationship.

Participants with more specialist technical knowledge were able to prolong the useful lifespan of the device, because they were motivated to engage with the technology.

A small group of participants subverted dominant modes of ownership, resisting the alienable nature of ubiquitous devices and expected modes of keeping. The personalised aesthetic of the devices in the 2 examples allowed the participants to express personal identity. These participants actively cultivated a more authentic relationship with the device, and through this challenged the culturally accepted transience of digital devices.

Devices in ‘Purgatory’ are often kept because the owners are not confident they have fully exhausted their use value, and because it hasn’t been necessary to dispose of them. This is not so much an extension of lifetime as a delay of end-of-life.

Interaction with a device can be an expression of emotional identity: physically maintaining a device in the long term (such as a modular PC) enables the user to cultivate a family relationship, and express care for family members.

Implications

The findings suggest that to encourage users to take an active role in extending the lifetime of their devices, designers need to provide more opportunities for them to physically engage with their devices, for example through modular products that people can upgrade and adapt themselves. This could provide more opportunities for positive emotional engagement. At present, non-commercial initiatives such as Access Space and the Restart Project support consumers in developing technical knowledge of their devices and physically engaging with them. Designers could also seek ways of challenging the anonymity of digital devices, by designing more authentic products that are designed for specific need rather than multiple functions.

Ultimately, consumer responsibility needs clarifying (Cooper 2004) and there are needs to industrial change, and the development of government policy to change the way that personal technology is designed and marketed. The current commodification of technology compromises user agency and we need to find alternative models of using, owning and keeping.

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A framework for understanding the role of product attachment in enabling sustainable consumption of household furniture

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Keywords: product attachment; product lifetime optimization; industrial design; sustainable consumption; household furniture.

Abstract: The study presented in here focuses on sofas to investigate the role of emotional product attachment with a view to reducing premature replacement of furniture products. A framework of four distinct product attachment and detachment factors in relation to the stages of ownership was devised for this research. The framework was applied to an online questionnaire and two sets of interviews among Australian householders, with the aim of determining behaviours in relation to furniture usage, maintenance and disposal. Questionnaire results suggest that furniture owners' purchase and maintenance behaviours regarding their current sofa are influenced by self-identity, lifestyle, affordability and social factors. The interviews indicated that product attachment can be fostered through more satisfying interaction between owners and their possessions. Long-term emotional attachment has implications for product lifetimes and is an issue that product designers can potentially. address.

Introduction

It is postulated that the lack of strong emotional bonds between product owners and their possessions, is one reason why objects are prematurely discarded. In psychological literature these deep and enduring emotional bonds are explained by the 'attachment theory', a concept which helps explain not only why we desire friendships and lasting interconnectedness, but also why we undergo separation anxieties.

Various authors have noted that as owners of possessions we often have particular objects which we cannot bear to part with, or which we particularly want to protect against damage. They suggest that there is an emotional bonding or a 'person-product relationship' that exists between owners and their special possessions (Davis, 2002). Behavioural attachment theory has been extended to the inanimate domain, and relabelled as 'product attachment' (Savaş, 2004; Mugge, 2007; Schifferstein et al, 2004)

Background

'Product attachment' can be defined as the emotional bond that a consumer experiences with a special and significant object (Mugge et al., 2004; Schifferstein et al., 2004) (Figure 1). This psychological connection and shared history results in the assignment of personalized meaning, which helps distinguish one's beloved teddy bear or mug from similar products on the market (Kleine & Baker, 2004) and signifies why consumers are more likely to hang on to certain products whereas they easily dispose of others (Schifferstein & Zwartkruis-Pelgrim, 2008).

Emotion and attachment to an object may be generated when there is a certain commitment or aspiration for a long-term relationship (Thomson et al., 2005). Thus even if circumstances become difficult, and in spite of love and hate moments, committed owners may be willing to continue the relationship with their possessions. This research proposes that product attachment results whenever there is a strong commitment and emotion towards a product (Figure 2).

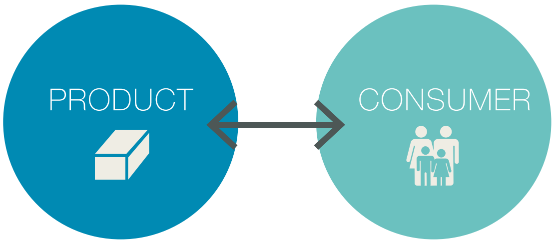

Figure 1. Product attachment.

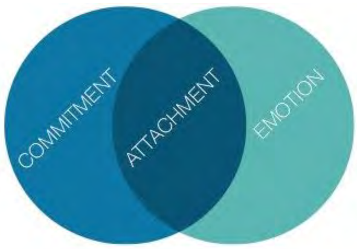

Figure 2. Relationship of product attachment, emotion and commitment.

People become attached to products for various reasons, such as recurrent pleasurable experiences during interactions, a suitable match with one's self-identity, and pleasant shared memories. After some time, the object means a lot to the person, to a point where emotional distress could result if damage or loss occurs (Schifferstein & Zwartkruis-Pelgrim, 2008; Savaş, 2004). These strong relationships have been seen to result in more protective behaviours towards products such as taking better care of belongings, preventing wear and tear, and treasuring mementoes of the past. In this sense product attachment may subsequently promote product longevity (Ball and Tasaki, 1992; Mugge et al., 2005).

Proposed framework

The framework developed for this research was adapted from the 'Four Pleasures' paradigm promoted by Jordan (2000) based on Tiger's (1992) theories on human behaviour and the biological mechanism of pleasure. The 'four pleasures' model embraces factors involved in product attachment where they have a positive influence on the 'person-product relationship' (Davis, 2002). Over the course of time, personal circumstances change and the previously strong relationship to objects might be diminished, leading towards feelings of detachment and subsequent disposal.

A categorization of possible product attachment and detachment factors, based on the four pleasures paradigm, is hereby suggested (Table 1). This classification acknowledges that attachment and detachment are strongly linked to the emotional, hedonic and practical benefits derived from association with our possessions.

Possible attachment factors	Possible detachment factors	Four pleasures (Jordan, 2000)
Physio attachment *Satisfying physical contact, aesthetic design, pleasant touch and smell*	**Physio detachment** *Product function failure, product wear and tear*	Physio pleasure
Socio attachment *Enjoying with others in a social or cultural setting*	**Socio detachment** *Change of social and cultural status*	Socio pleasure
Psycho attachment *Cognitive and emotional reactions, memories to person, place and event*	**Psycho detachment** *Undesirable past self*	Psycho pleasure
Ideo attachment *Alignment with personal values and ideology*	**Ideo detachment** *Altered ideology*	Ideo pleasure

Table 1. Factors of attachment and detachment. Source: adapted from Jordan, 2000.

Another categorization of product attachment and detachment stages, based on Ball and Tasaki's (1992) 'ownership stages' model, as well as Davis' (2002) 'person-product relationship' lifecycle model, is presented in Table 2.In general, the first three ownership stages are related to positive relationships, whereas the last two carry negative connotations. However, it is expected that a product owner would experience feelings of either attachment or detachment with some of their possessions during various ownership stages, which could either stimulate or dampen their relationship with the product, and thus provide the motivation to either move on to next stage or terminate ownership. For example, if the experiences with a product were positive, the relationship would progress to the mature ownership stage; if the experiences were negative then the relationship with the product would break down and the owner would move on to the pre-disposition stage directly.

On the other hand, even though the person-product relationship was negative at the predisposition stage (signalling detachment) a consumer might positively try to extend their association by refurbishing it or finding alternative uses (signalling attachment).

Possible attachment & detachment stages	**Ownership stages** (Ball & Tasaki, 1992)	**Product-person relationship lifecycle model** (Davis, 2002)
Pre attachment / detachment *Before product is purchased*	Pre-acquisition	First encounter
Early attachment / detachment *Soon after product is purchased*	Early ownership	Commitment + Honeymoon period
Mature attachment / detachment *After product is being used for some time*	Mature ownership	
Pre detachment / attachment *Thinking of discarding product*	Pre-disposition	Relationship breakdown
Post detachment / attachment *After product is discarded or transferred*	Post-disposition	

Table 2. Stages of product attachment and detachment linked with ownership stages. Source: adapted from Ball & Tasaki, 1992; Davis, 2002.

The two categorizations were integrated into a singular model, which is the proposed framework of this study. This framework reveals how the factors of product attachment and detachment occur in relation to ownership stages (Table 3).

OWNERSHIP STAGES	PHYSIO ATTACHMENT/ DETACHMENT	PSYCHO ATTACHMENT/ DETACHMENT	SOCIO ATTACHMENT/ DETACHMENT	IDEO ATTACHMENT/ DETACHMENT
PRE-ACQUISITION				
EARLY OWNERSHIP				
MATURE OWNERSHIP				
PRE-DISPOSITION				
POST-DISPOSITION				

Table 3. The proposed framework describing the relationship between ownership stages and attachment and detachment factors. Source: adapted from Ball & Tasaki, 1992; Jordan, 2000.

The top row of the framework indicates the four factors of product attachment and detachment, while the left column shows the five ownership stages. One or more attachment and detachment factors can apply concurrently within any stage of ownership and particular factors might increase or decrease in relative influence during the stages of ownership.

Methodology

The present study intends to test the proposed framework, and to explore how it could describe product attachment of various types and at various ownership stages.

A decision was made to limit the study to one product type only, and the product selected was the 'sofa' (aka 'couch' or 'lounge seat'). This product was deemed appropriate for exploring the presence of long-term attachment, as they are less likely to be driven by technology fads, do not consume energy during use, and are often found dumped on the streets; however they can have potentially long lifetimes if they are well-made.

Questionnaire	Ownership stages	Description	Example of question: evaluate your agreement
Part A	Pre-acquisition	These questions are related to your purchase decision.	If you were to buy a new sofa what would be your main concern?
Part B	Early ownership	These questions are related to your immediate satisfaction with your current furniture.	If you have owned your sofa for less than 2 years what pleasures did you get from it?
Part C	Mature ownership	These questions are related to your long-term satisfaction with your furniture.	If you have owned your sofa for more than 2 years are you still satisfied?
Part D	Pre disposition	These questions are related to your dissatisfaction and motivation for replacing your furniture.	Thinking forward what could be the trigger or motivation for you to replace your sofa?
Part E	Post disposition	These questions are related to the life of your furniture beyond your ownership.	If you were to replace your current sofa what would be the main reason?
Part F	These questions seek general information about you, your household, and your dwelling.		

Table 4. Structure of online questionnaire used in the study.

A five-part online questionnaire (Table 4) was administered to determine the behaviour of Australian householders in their furniture usage, maintenance and disposition, and to investigate their degree of attachment to their furniture as well as the motivations for their underlying detachment. Webmasters of Australian consumer blogs and discussion forums assisted in emailing the questionnaire hyperlink to their members and subscribers; this process yielded 100 valid responses.

From the pool of questionnaire respondents, four volunteered to be interviewed; they are profiled in Table 6. Eight key questions were developed from the framework to investigate consumer attitudes and behaviour in depth. Interviewees were requested to bring a photograph of their most-used sofa. The purposes of the questions in relation to factors of product attachment and detachment are detailed in Table 5.

The research direction was reviewed after the interviews and it was decided to interview people who described themselves as 'sustainability minded'. These additional participants are profiled in Table 7, and the additional questions asked are listed in Table 8. This extra step intended to find out whether the two groups of interviewees demonstrated different purchase motivations and maintenance behaviours with their sofas.

	Subject area for key questions	Question
1	Introductory question	Q1. Tell us about your current sofa.
2	Satisfaction/ dissatisfaction	Q2. Why do you like/dislike your current sofa?
3	Four pleasures and four attachments	Q3a. If you are satisfied with your current sofa, what pleasures do you get from using it? Q3b. If you are dissatisfied, what pleasures were you expecting to get from owning it?
4	Long term satisfaction and early / mature attachment	Q4. How long have you had your current sofa for? Q4a. If you owned your sofa for less than 2 years: is your sofa still "as good as new"? Does it still match your life style well? Q4b. If you owned your sofa for more than 2 years: would you rather keep your current sofa than replace with a new one? Why?
5	Product replacement motivation	Q5. If you were to replace your current sofa, what would be the main reason?
6	Product purchase decision-making	Q6a. If you were to buy a new sofa, will you choose something similar to the one you had? Why? Q6b. What do you consider the most important factor when purchasing a new sofa?
7	Post detachment	Q7a. Would you pass your sofa on to someone who needs it or would you sell it? Q7b. Would you like to know what happens after you have discarded your sofa? Why?
8	Concluding questions	Q8a. What do you think is the average life span of a sofa? Q8b. What should the designer be aware of when designing for long-term product attachment?

Table 5. Semi-structured interview questions.

Person's characteristics	Interviewee 1	Interviewee 2	Interviewee 3	Interviewee 4
Gender	Female	Female	Male	Male
Country of origin	United Kingdom	Australia	South Korea	Australia
Name initials	D.M	J. E.	S.H.	M.F.
Age category	Early 50's	Mid 40's	Late 20's	Mid 30's
Rest of household	Husband and two dogs	Husband and one child	One female and one male flat mate	Wife
Occupation	Unemployed	Graphic designer	Project manager	Studio manager
Relevant circumstance	Currently building a new home	Planning to relocate home	Socially active	Newly married
Interview date	15 Jan 2010	11Feb 2010	4 Mar 2010	17 Mar 2010
Photograph of sofa				

Table 6. Profiles of participants in first set of semi-structured interviews.

Person's characteristics	Interviewee 5	Interviewee 6	Interviewee 7	Interviewee 8	Interviewee 9	Interviewee 10
Gender	Female	Male	Female	Female	Male	Female
Country of origin	Australia	India	Australia	Hong Kong	Australia	Australia
Name initials	K. C	R.K.	J. N.	M L	G. C.	E.Y.
Age category	Mature adult	Adult	Young adult	Adult	Mature adult	Adult
Rest of household	Husband and kids	Wife and a daughter	A flat mate	Parents	Wife	Husband
Organizational affiliation	Social Innovation Sydney	GreenUps	The Bower	GreenUps	Society for Responsible Design	GreenUps
Interview date	21 Nov 13	19 Nov 13	20 Nov 13	18 Nov 13	12 Dec 13	15 Jan 14
Photograph of sofa	No photo		No photo			

Table 7. Profiles of participants in second set of semi-structured interviews.

	Subject area for key questions	Additional question
2	Purchase decision	Q2. Who made the decision when purchasing your current sofa? What were the main concerns?
5	Long term satisfaction and early / mature attachment	Q7. What have you done to maintain or repair the quality of your current sofa?
6	Product replacement motivation	Q10. Are there enough sustainable product options when purchasing sofas?
7	Sustainability	Q11. What should buyers consider when purchasing sofas in order to avoid premature disposal?
		Q12. How can designers enable owners to keep their sofas longer?
		Q13. Please comment on the possibility of extending products' physical and psychological lifetime.

Table 8. Additional questions for second set of interviews.

Results and discussion

Online questionnaire

More than half of the surveyed males considered their furniture as being unique and personalised, and that they like to take a photograph with their friends or family of their sofa to share a meaningful moment; in contrast only a quarter of females shared these views (Figures 3 and 4). Younger consumers aged 18 to 44 tend to be more driven by contemporary design and colour schemes than older consumers aged 45 to 65 (Figure 5). The youngest consumer group indicated that the length of the warranty period offered was not important to them (Figure 6). It appears that younger people are less likely to experience mature attachment with their products, whereas older consumers with no intention of changing their current furniture seem to have more opportunity to establish an enduring and mature attachment. In addition, younger consumers aged 18 to 24 tended to buy more economical furniture, thus making length of warranty less important to them. Consequently, there is a tendency to replace items of furniture when they can afford better ones, subsequently resulting in increased attachment and relationship with their furniture as they become older.

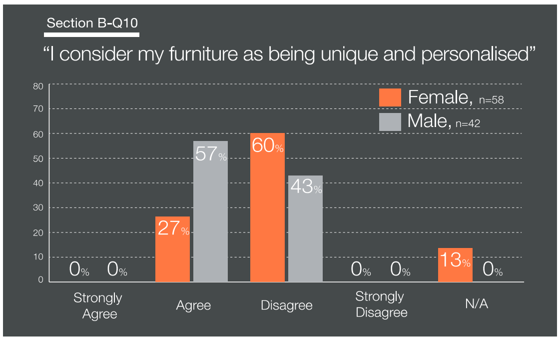

Figure 3. Agreement with statement on 'personalisation' by gender.

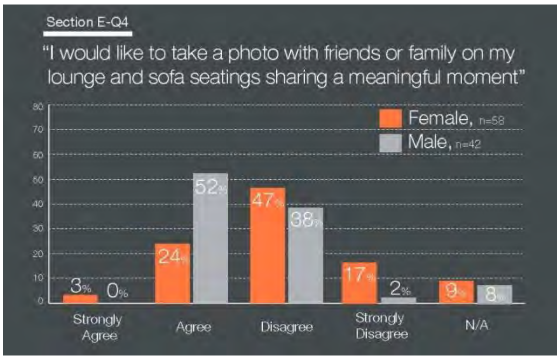

Figure 4. Agreement with statement on 'meaningful moments' by gender.

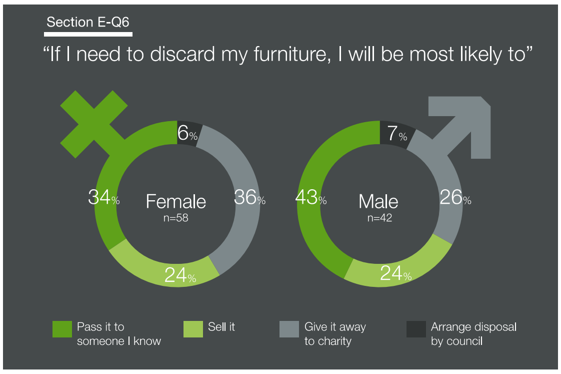

Figure 7. Preferences with the statement on 'unwanted furniture' by gender.

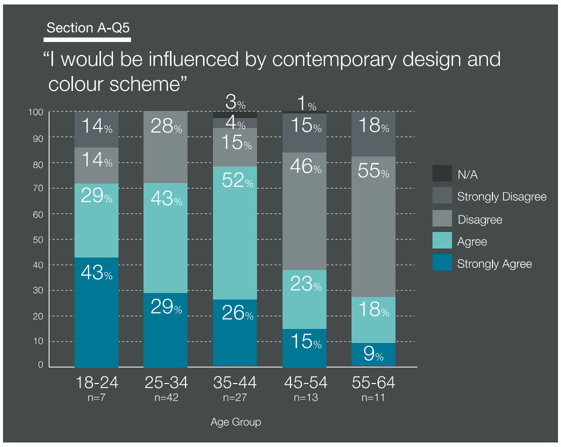

Figure 5. Agreement with the statement on 'fashion and trend' by age.

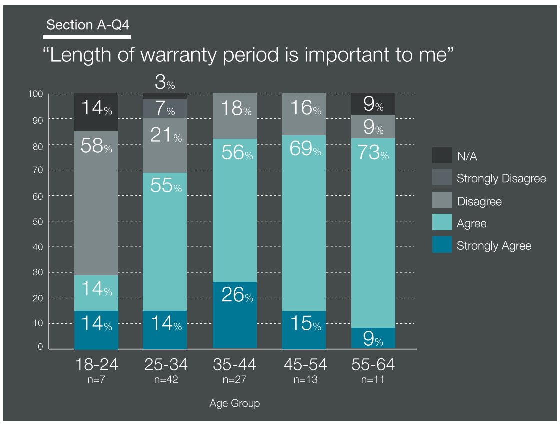

Figure 6. Agreement with the statement on 'length of warranty' by age.

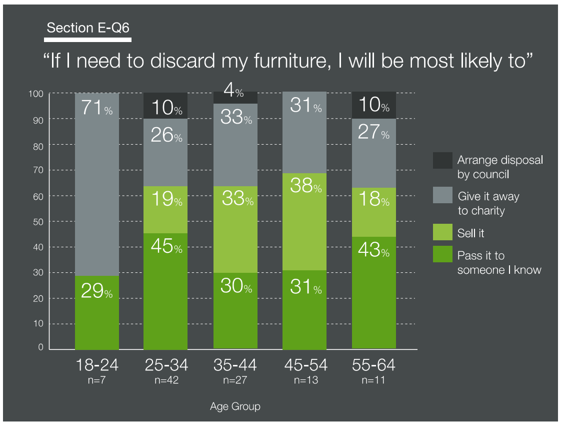

Figure 8. Preferences with the statement on 'unwanted furniture' by age.

Overall, 94% of respondents agreed they would either pass their current furniture to someone they know, sell it or give it away to charity rather than organizing a council service to pick it up for disposal.

The views of men and women about unwanted furniture were similar (Figure 7). Interestingly, over 70% of younger respondents aged 18 to 24 stated that they would give their furniture to charity rather than sell it, whereas only an average of 29% of respondents aged 25 to 64 would give it to charity (Figure 8).

Having been designed to follow the stages of ownership, the online survey revealed not only the extent of owners' emotional attachment to their sofas but also the different levels of affection at different phases of possession; these are summarized in Table 9.

Ownership stages	Consumer behaviour
Pre-acquisition	Consumers spend much time and effort to investigate sofa.
Early ownership	Consumers with less than 2 years of ownership experience immediate satisfaction.
Mature ownership	Consumers with more than 2 years ownership take care and periodically change covers and cushions to extend satisfaction.
Pre-disposition	Consumer's replacement motivations are influenced by 'external factors' such as newer and more attractive products.
Post disposition	Consumers would like to know if the company provides a take-back service.

Table 9. Consumer behaviour over product ownership stages.

Semi-structured interviews

When a furniture piece has become less interesting and less reflective of its owner's identity and lifestyle it is often placed in a less prominent area of the home (Lastovicka and Fernandez, 2005). This ritual of transitioning from being a 'me' to a 'not-me' object marks the initiation of the detachment stages for the product. In this case, owners may have lost their physical, psychological and sociological attachment with their current furniture. However, their ideological attachment, springing from their concern for the environment, might prevent them from disposing of the furniture completely. This was confirmed in the account of Interviewee 1, a married female in her early 50s who owns a sofa with brocade-like upholstery (Figure 9), when asked: 'Q5 If you were to replace your current furniture, what would be the main reason?'

"We are building a new house, and I am thinking of getting a new lounge suite for our new home. However I would like to keep the current lounge suite; my lounge is old and I want something new for the new start. But it still does its job and I can still sit on it! But we will probably move them to upstairs or the garage so we can still use them and have the new ones in the main lounge room. I just don't like throwing stuff out easily; it is not good for nature and all of us."

Figure 9. Sofa of Interviewee 1.

The proposed framework was tested amongst Interviewee 1's responses regarding her current furniture (Table 10). At the pre-disposition stage she experienced a fusion of physio detachment (*"it is old"*), psycho detachment (*"I want something new for a new start"*), socio detachment (*"new home"*), and ideal attachment: (*"I just don't like throwing stuff out easily"*). However she was trying to find a way to keep her current furniture because she experienced idea; attachment at the post-disposition stage (*"I'd like to move it upstairs or to the garage so we can still use it"*).

Notably, sustainability-minded sofa owners appear to have better maintenance behaviour with their furniture compared to conventional householders. They seemed to enjoy the time spent in maintaining their sofas. Interviewee 9, a married mature adult male, had two sofas: a geometric 1970s sofa and a classic-look 1990s sofa with removable covers (Figure 10). He described his experience of reupholstering his old sofa in response to this question: 'Q8 What have you done to maintain or repair the quality of your current sofa?'

Ownership stages	Physio Attachment or Detachment	Psycho Attachment or Detachment	Socio Attachment or Detachment	Ideo Attachment or Detachment
Pre - acquisition				
Early ownership				
Mature ownership				
Pre - disposition	D	D	D	A
Post - disposition				A

Legend		
	A	*Attachment*
	D	*Detachment*

Table 10. Attachment or detachment of Interviewee 1 at pre-disposition stage as analysed by the framework.

"I have two lounge seats: one from the 1970s and other one from 1990s. I need to fix a few problems with the 1990s lounge that I am using. The side is not sprung properly so I had to find a better spot to sit on the sofa. I think it is due for re-springing and a new cover as well. I have reupholstered the other lounge (1970s) three times already and I did really enjoy the process of recovering its quality. It was a great project for me to get involved in when I was working as a freelancer: I had some extra time. Next time, I would like to use organic cotton fabric for the cover. It is my new challenge".

The pleasurable involvement of Interviewee 9 with his old sofa was not only associated with product utilization but also with other activities that involved hands-on experiences and commitment to product maintenance. His positive emotional reaction is beyond the person-product relationship, as the service was carried out by the owner himself, rather than the after-care services provided by a furniture-repair company. The satisfaction and meaningful interaction derived from this self-repair process might encourage further preservation desires for his other possessions, such as reupholstering his 1990s sofa. In this way, positive attitudes and behaviours could gravitate towards more sustainable outcomes.

Figure 10. 1970s sofa (top) and 1990s sofa (bottom) belonging to Interviewee 9.

The purchase motivation of the second set of interviewees was predominantly driven by sustainability and environmental concerns, such as high return on investment, durability, craftsmanship and timeless aesthetics. In addition, the group has a pronounced interest in second hand furniture with the intention of optimizing the lifetimes of used products.

It is possible that the two factors, long-term relationship and commitment might help to distinguish attachment from emotion. It is widely accepted that emotion is not restricted to the length of ownership, as anyone can instantly fall in love with a nicely designed product. The attachment aspects for sustainability minded consumers could be represented in Figure 11.

Figure 11. A diagram of attachment aspects for sustainability-minded consumers.

Conclusion

Sustainability can have conflicting implications in different situations. In order for products to be considered sustainably designed, ecological principles, particularly conservation of resources, must be both the basis of and foundation for production. Additionally, the extension of a product's psychological lifetime should be given equal importance to its physical lifetime in order to circumvent premature product disposal. If products are well-designed, consumers need to derive persistently pleasurable and satisfactory interactions from their use and such enjoyment could enable them to become attached to their possessions.

An obvious benefit of the proposed framework is its potential to support designers in their product development process by means of user scenarios that can be evaluated via the attachment and detachment factors that are inherent in the framework. With this scaffold designers can be assisted in exploring and enhancing the satisfying attributes and pleasurability values that can be embedded into new products and that could promote emotional attachment. Sensitivity to these can help foster stronger person-product relationships during the entire period of ownership, and support the consequent extension or optimization of the overall product lifetime. Ultimately an attachment-oriented solution can encourage consumers to consider retaining their possessions for as long as possible and to avoid their premature disposal.

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Age and active life of clothing

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Keywords: clothing life span; longevity; product lifetime; active use.

Abstract: The purpose of this paper is to provide data on clothing concerning life span and length of active use period, as very little information is available. The article is based on a study of 620 clothing items that 16 households (35 people) disposed of during six months. A wardrobe study method was used, which included clothing registrations and in-depth interviews based on the selected pieces of clothing. The informants reported on the disposal reason for each item, how much it had been used, and how long they had owned it.

The clothes that went out of use had an average total life span of 5.4 years and had been with the current owner for the past four years. This suggests that many of the clothes had been inherited or purchased used. Total life spans ranged from brand new to about 50-year-old garments. Clothes for children and teenagers had shorter average life spans, while adults above the age of 51 disposed of clothing 4.6 years older than the average.

Our results indicate that the total life spans were longer than most previous research has estimated. However, many of the items had been used very little: 8% had never been used by anyone, and every fifth garment was either never used or had been used only a couple of times by the current owner. More research is needed, especially concerning the active use period, such as number of use times and differences between various consumer groups.

Introduction

Very little information is available of actual life span and use per unit of clothing. The purpose of this paper is to provide more realistic data for clothing LCA studies concerning the estimated longevity (age) and the period of active use. To be able to do provide this data, it is also necessary to discuss the relationship between life span and use, and to discuss the methods we have available for uncovering relevant information on these matters. Based on an overview of previous studies, the paper shows the uncertainties inherent in existing knowledge. This knowledge gap could potentially be filled through a quantitative analysis of data on wardrobes and clothing disposal. The data is valid for a Norwegian context, but literature on available data from other countries is also discussed.

Background

Textile and clothing industry combines high speed and low-cost production with high volume consumption, which causes significant environmental impacts (Fletcher, 2008; Fletcher & Grose, 2012). From an environmental point of view, prolonging product life span can have several advantages (Cooper, 2010). A short life span increases the need for products to be replaced faster, hence increasing the environmental impact from the production, transportation and disposal phases.

The length of life span and intensity of use of clothes varies widely. The oldest existing Norwegian garment is 1700 years old (Guhnfeldt, 2011), and we have clothing in use today that is over 100 years old (Lilleby, 2014), while some clothes are only used once or not used at all (Laitala & Boks, 2012). A garment can be used by multiple users who take turns, for example through sharing or renting, or by multiple users who own the garment in a sequential order, for example through inheritance or so-called second-hand purchases (Klepp & Laitala, Unpublished). Clothing’s life span is dependent on both the technical and social robustness, and the flexibility of the apparel. The relationship between the length of life span and number of use times is complex. Owning a large number of clothes increases the chance that a given garment is used rarely, and thus many years may pass before such items are worn out. Measuring life alone will therefore not offer information about resource efficiency unless the number of uses per item is taken into account.

Very little information is available on actual life span and use per item of clothing. For example, two separate studies estimate life span of clothing items as varying from ten up to 104 uses (Birtwistle and Moore 2007; Collins and Aumônier 2002). Beton et al. (2014) have estimated that all garments have a life span of 1-3 years, but they refer only to their own and others' estimates that are not documented by research. A large survey based on respondents' own estimations found that the average active use of clothing is 3.3 years (Langley et al., 2013). A Dutch study estimated that the average lifespan of trousers was 6.2 years, skirts and dresses 15.2 years, sweaters 7.1 years, blouses 7.2 years, t-shirts 6.8 years, blazers 11.5 years and jackets 11.6 years (Uitdenbogerd, Brouwer, & Groot-Marcus, 1998, p. 127). The life span of a skirt was thus estimated to be twice as long as that of a pair of trousers. The calculation was based on the number of garments in 16 households and correlated with how much was purchased by the household. In her PhD study, Uitdenbogerd also asked survey respondents about how long they used two different garments before they were disposed of, and the result of cotton trousers was 2.45 years, for wool sweaters the average was 6.17 years (Uitdenbogerd, 2007, p. 281). The differences between the results of these studies are quite substantial. This confirms how uncertain indirect means of estimating garment life spans are. As we do not know enough about what contributes to clothing longevity, when such figures are used in LCA studies, the results will hardly be realistic.

Method

In order to obtain more reliable knowledge about the use phase, we have used a method that examines families' wardrobes and enables a comparison between the quantity of clothing, their technical condition and social life. The article is based on studies of clothing that 16 households disposed of during a six month period. During the project period, the total of 620 garments were taken out of use and registered. The households consisted of 35 people totally and each participant stopped using on average 18 garments; however the figures varied from 0 to 71 items per person. A so-called *wardrobe study* method was used, which includes clothing registrations and in-depth interviews based on the selected pieces of clothing.

Households were selected strategically, the goal being to interview people in different life situations. They were placed in three main groups: 1) young adults without children, 2) parents of small children and 3) retired or soon to be retired adults.

The informants reported the disposal reason for each item, how much it had been used and how long they had owned the item. Clothes were evaluated afterwards in a textile laboratory, and their condition was registered in detail including whether the garment had holes or rifts, stains, pilling and how worn it looked. In addition all other available information was registered, such as colour, brand, and all data given on the apparel labels. The goal was to compile comprehensive information on clothing practices including all the stages of consumption from acquisition, use, care, to disposal. This paper presents the results that are relevant for LCA studies related to length of life spans and active use.

Results

Information on clothing life spans is given in Figure 1. The clothes that went out of use had an average total life of 5.4 years, and had been with the current owner for the past four years. This shows that many of the clothes were inherited or purchased used. The total life span ranged from brand new to about 50 years.

Clothing that adult men disposed of, had on average a 1.5 years longer life span than women's clothing in the study. However, the difference was not significant to 95% level (P=0.059) due to the small sample size for men's clothing.

Clothes for children and teenagers had the shortest life spans, while adults above the age of 51 disposed of 4.6 years older clothing than the average. In Klepp's study, the mean lifespan of the clothes of 40-year-old women was 7 years (Klepp, 2001). In our data material, clothing for this group was used slightly shorter, namely 5.2 years. This may be due to a growth

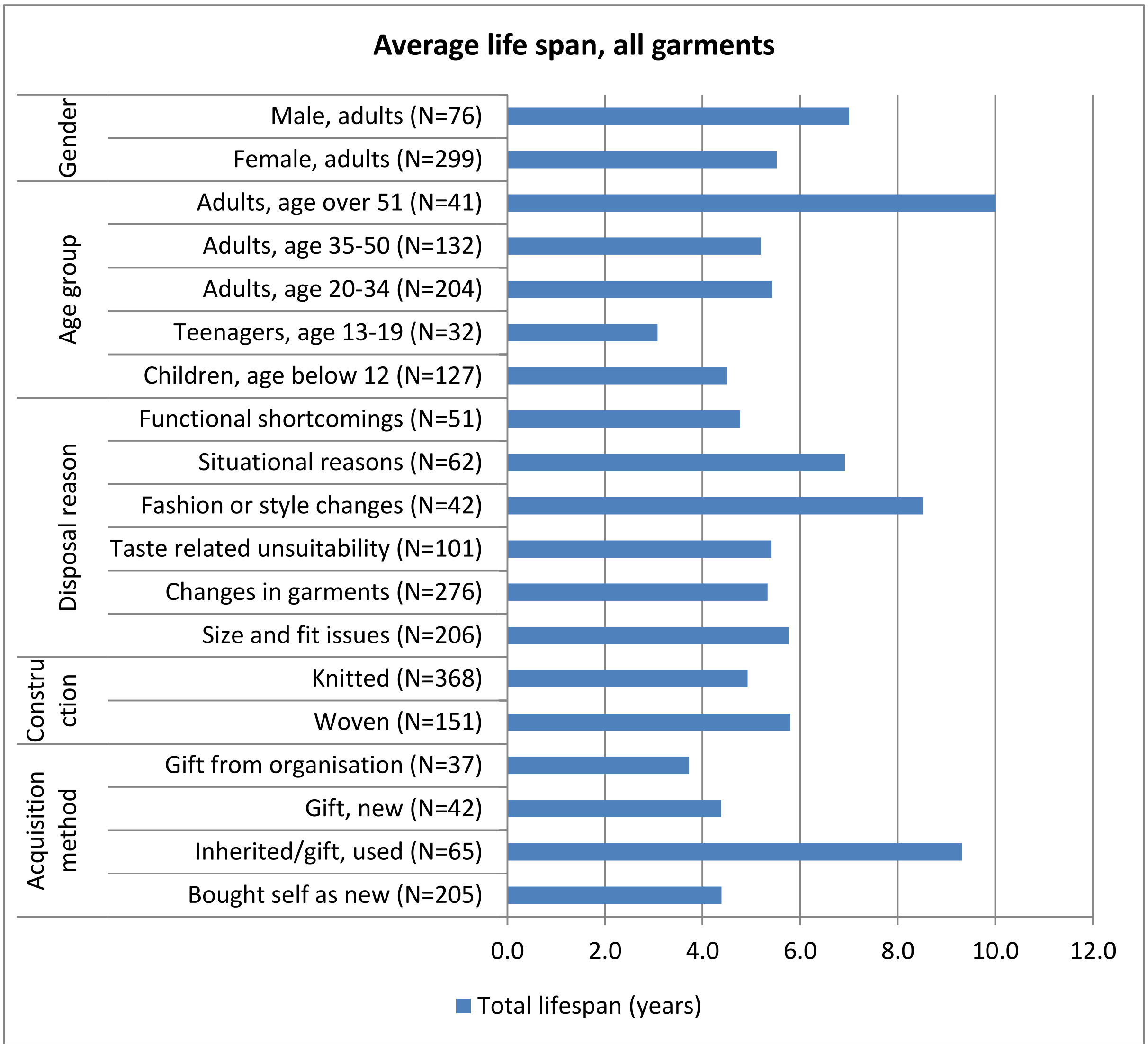

Figure 1. Average length of clothing life spans. N indicates the number of clothing items

in prosperity in the time-span between the two studies, but can also be due to differences in the sample, or other methodological aspects.

The life span of the clothes was almost identical regardless of whether the plan was to give or sell the garments for reuse, or to throw away the apparel. However, there was a difference in use time for the current owner related to disposal plan. The use time was 1.6 years shorter for the clothes that were to be given with an aim pf prolonged use, than for those that were to be discarded. Therefore, these clothes had a potential for new use periods with new owners and thus longer total life span. The degree of wear was an important criterion for what the owner planned to do with the clothing. The clothes that owners reported were disposed of wholly or partially due to fashion changes, were on average 3 years older than average of all the disposed clothes. Clothing disposed of due to situational reasons were 1.6 years older than average. Clothing with functional defects, however, had been used for half a year shorter than average. Clothing with various changes in the material had an average life span, which is understandable based on the large proportion of the clothes in this category. When comparing the different degrees of wear and tear, clothes that were described as worn out had a useful life of 4.2 years (one year below average), while those described as having a worn look had a life span of 7.3 years (two years above average). The clothing that was described as washed out had a long life span, 10.9 years, which is 5.5 years above average. If the clothes had been damaged by laundering, the average use time was reduced. Colour bleeding during washing reduced use life with 2.5 years, and shrinkage with 1.6 years. It is not clear how the informants have drawn a line between products that they described as having a worn look, being worn out, or being washed out, but it is likely that washed out products have been used and laundered often, and show signs such as thinning of material and colour fading. Clothes that were disposed of because of a change in living circumstances were 3 years older on average. Uncomfortable clothes were discarded faster, and their life span was a year shorter.

In Klepp's (2001) study the clothes that went out of use because of fashion, had the same life span as clothing that was disposed of because of wear (approximately 8 years), but the "out of fashion" clothes had been stored longer between the time of disposal and the last time they were used. In both the Klepp study and the present study, these "out of fashion" clothes remained equally long stored "at mercy", namely 2.8 years. It is not known if this storage time affected the degree to which fashion is used as an argument for disposal. It is conceivable that the clothes were to a lesser degree deemed as obsolete when they were last used, 2 to 3 years earlier, than at the time the owner described them as too outdated to be used. Other reasons for not using the garment might have been more important then.

As expected, different types of garments have different life spans. Many of the smaller items that were often described as "consumables" such as socks, stockings, and underwear, have shorter lifespans. This result was also found in the survey by Langley et al. 2013. Nightwear and outerwear had above average life spans. At first sight, the fabric structure seemed to contribute as well, as woven materials have slightly longer life spans than knitted. However, much of the clothing referred to as consumables (socks, stockings and underwear) are made of knitted materials, and these types of garments in general have shorter lifespans than other types of garments. When these are excluded, the woven and knitted items have the same lifespan, 5.9 years.

Never used

Our results indicate that the total life spans were longer than the aforementioned estimates indicated in other studies. Many of the clothes had been used very little. 8% of the garments were never used, and in total every fifth garment was either never used or used only "a couple of times" by the current owner. This is consistent with findings in Klepp's study, where the corresponding figures were 9 and 19% of the clothes (2001). Most of the unused clothes were gifts or inherited clothing items from family and friends. In these cases the receiver had very little control over what she/he was given. In other cases, rarely used items consisted of clothing that was not tried on before purchase, or that was bought on sale. It is evident that the way clothes are acquired has an impact on whether they are likely to be used.

Many clothes had been lying unused in the wardrobe for years before they were disposed of. The average time lapse from last use time, was 1.4 years. It was common that children's clothing was disposed of sooner when the apparel no longer fit. On average, they were used for the last time seven months ago, while the average for clothing for adults, was 1.7 years. We have not taken into account that the clothes can have been stored a few months before our visit and registration. On the other hand, it may also be that some clothes were taken out of use because of the research project, and thus had shorter waiting time than average.

Conclusions

Our results indicate that the total length of clothing life spans were longer than most previous research has estimated. However, much of the clothing had been used very little. 8% of the garments were never used, and totally every fifth garment was either never used or used only a couple of times by the current owner. In addition, the active use period is much shorter than the total life span. The average time lapse from last use time was 1.4 years.

Our data material is not large enough to draw firm final conclusions. However, some interesting findings were found. The way clothing is acquired has great influence on the length of life span. This should be drawn into future LCA calculations. For example, clothes that are given as business gifts are seldom used and have therefore a higher environmental impact than corresponding garments acquired by the users themselves.

More research is needed, especially concerning the active use period such as number of use times, and differences between various consumer groups.

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Transitions in waste treatment as a driver for product life extension

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Keywords: destabilising incineration regime; emerging shredding regime; refurbishment and reuse initiatives; ambiguities in waste management practices; refurbishment initiatives as transition mediators.

Abstract: Increasing amounts of energy are used for provision of resources. Recycling, refurbishment and reuse practices are recurring elements in visions of the future low carbon and resource efficient society. Visions of improved waste management practices are, however, confronted with the inherent tensions between current incineration practices and options for waste prevention, sorting at source and recycling.

Denmark has for the past 30 years developed and continuously improved waste incineration technology, which combined with use of the energy for district heating, has become an energy efficient waste treatment process. Previously improved treatment of waste was perceived as closely linked to waste incineration technology and widely shielded from the contextualisation of demands for increased reuse, recycling and improved resource efficiency. This regime seems now gradually to become somewhat destabilised due to increased EU demands for waste recycling, and new opportunities for pursuing strategies of increased product lifetime appear. Swapping and local repair initiatives can be seen as examples of such opportunities. These initiatives link nicely to e.g. policy visions of circular economy that emphasise prolonged product life and stresses the importance of avoiding down cycling of products and material streams. The destabilisation of the old incineration regime thus opens up for new opportunities with both new policies and potentially new social practices.

This paper describes a number of the above-mentioned refurbishment and reuse initiatives and analyses how they engage with the dominant waste treatment regimes. We investigate how these initiatives may take advantage of the ambiguities and tensions, which appear in the break-up of the old regime. In doing this we conceptualise refurbishment and swap initiatives as mediators that generate transformative change by displacing the boundaries and interdependencies within and among the established socio-material order of waste management.

Introduction

Repair, refurbishment and reuse of old products that would otherwise have been lost as waste are important elements in the strategies of the circular economy model, which aims to prolong the life of products and loss of materials. Therefore it is important to investigate strategies to support various reuse strategies. Reuse requires that used products are either swapped, repaired and/or resold before they enter the waste stream or that they are identified and separated after collection in the waste stream. Products are considered waste when they are collected with the household waste or delivered to the public waste management facility. Accordingly preparing products for reuse must be a common element of waste treatment and increased product reuse depends on the setup of the existing waste management system. At European level there are big differences with regards to how waste is collected and treated. In Denmark waste from the construction industry has a very high level of recycling. Wooden elements are recycled as wood fibers or through incineration with heat recovery. Non-organic and non-metallic elements (gravels, cement plaster, pottery, tiles, etc.) are widely recycled as stable construction filler. Other organic material (plastics) is also incinerated with heat recovery. Some Danish cities have the recent years developed material recycling of household plastic waste, although with big problems in achieving a high level of material recycling. The vast majority of the reused waste originates from the construction industry. Regarding household waste, separate collection systems for glass and paper are in function, but a large developed material recycling of household plastic waste, although with big problems in achieving a high level of material recycling. The vast majority of the reused waste originates from the construction industry. Regarding household waste, separate collection systems for glass and paper are in function, but a large fraction is still incinerated together with the rest of the household waste. As a result about 50% of many metals are lost in the incineration slag. Statistically Denmark is in the mid-range (Figure 1) when it comes to reuse, but at the same time the European country with the highest share of waste incineration.

Figure 1. Treatment methods of publicly collected waste in EU 2010. There are big differences with regards to the proportions of recycling, incineration and disposal. Source: Based on data from Danmark uden affald, Regeringen 2014.

This paper investigates how the Danish waste management system is motivated to implement new reuse initiatives under influence of demands of increased product recycling such as the EU target of recycling 50% of the 'dry' household waste (glass, metal, paper etc.) by 2020. The response is identified as changes in specific processes such as swap sheds and repair workshops but also as changes in market structure, user behaviour and regulation. Preparing waste/products for reuse is accordingly conceptualized as a question of transforming the waste management system. Our analytical approach is to understand these systemic changes as elements in sustainable innovation and we use the framework of transition theory to describe the waste management system as an established socio-technical regime.

The paper proceeds with a brief introduction to the concept of socio-technical regimes. This is followed by five brief examples of interaction between reuse initiatives and the existing waste management regimes. The empirical material for this section consists of personal communication and public documents and still needs to be further developed. Finally the paper returns to the question of the challenges of introducing prolonged product life through reuse with multiple owners as a waste treatment alternative to incineration or crude material recycling.

The regime concept

The theoretical argument draws on the idea that industrial activities tend to become institutionalized in regimes whose development is characterized by path dependencies. The path dependent development of regimes implies that specific concerns such as environmental performance are only likely to develop to a point where core regime interdependencies and power structures are not compromised (Geels, 2003; Jørgensen et al., 2007). It is then argued that more and dedicated regime independent development processes may help incumbent regimes to evolve more efficiently by illuminating the possibility of radical alternatives.

The idea of the regime concept as it was originally outlined by Nilson and Wither (1982) is that the problem solving activities of engineer communities over time are likely to develop dominant problem framings and search heuristics, which may on the one may increase efficiency by giving direction to the activities of the community but which on the other hand may also render it blind to alternative problem framings and search heuristics (Kemp et al., 2001). During the past decades this notion of regimes has been gradually expanded along two dimensions. First the concept is no longer limited to the practices of engineer communities. The concept is thus increasing used to explain the direction of broader industrial and societal development processes. Secondly the concept is no longer concerned only with problem framing and search heuristics but has rather been developed to include the broader socio-technical interdependencies and reciprocities underlying established societal practices (Kemp, 2007). Waste management is an example of such interdependencies as it is interrelated to a diverse set of consumption practices, collection systems and infrastructure, market dynamics and waste treatment technologies.

In terms of agency the regime concept implies that everyday practices as well as more deliberate strategic development activities tend to be shaped and conditioned by the prevailing interdependencies and reciprocities characterizing the regime (Berkhout, Smith & Stirling, 2003). Regimes are thus characterized by a set of stabilizing mechanisms which also give direction to development processes such as (i) interdependencies between technologies, regulation and standards (ii) power structures, identities and interests implicit to the division of work division and formally represented by the development of professional interests organizations (iii) cognitive structures and frames which guide the perception of problems and solutions. The current Danish waste management regime is accordingly characterized by the interdependencies between incineration, public ownership of district heating infrastructures versus private ownership of waste as a result of the recent liberalization in the waste sector. Cognitive framings of waste reuse are weakly interlinked and experimental compared to the heavily institutionalized setup of the incineration regime. Because regimes work to focus attention and align a variety of socio-technical structures in a working configuration regimes may be highly productive and innovative for certain purposes at certain periods. In the Danish case the abolition of atomic power has spurred the development of highly efficient coal fired CHP power plants (also for international export). These combined heat and power plants are however, also highly efficient in utilizing the calorific value of the waste content. Hence most recycling alternatives appear inefficient within the current system setup: Using organic waste for biogas, sorting out plastics and wooden elements from the incinerated fraction will require increased use of coal as compensation.

Embedded actors may find it both unattractive and difficult to develop strategic visions, which do not reify existing regime logics and interdependencies and they may find it even more difficult to mobilize the socio-technical resources, which it takes to materialize regime independent visions of development. In this sense the development and transformation of regimes are argued to be characterized by so-called path dependencies. However, because regimes are structured and because their development path is organized towards addressing certain ends at the expense of others they may be highly counter-productive in addressing alternative ends. Regime specific development paths oriented towards optimizing productivity or user comfort may e.g. be difficult to reconcile with environmental concerns.

In real life regimes and the development path which they define are however less monolithic than indicated above. Development paths are accordingly likely to be characterized by a complex of ends and interests which may be partly contradictory. As much as certain development path characterises a regime, this gives direction to change such a path according to the outcome of a complex of compromises and trade-offs. This entails that dominant development paths to a certain degree will be capable of absorbing new concerns even though the implication of addressing these concerns may contradict with the established orientation of the development path. In the incineration regime separate treatment of distinct fractions such as paper recycling have been gradually accepted.

However, the realization of these concerns should not compromise core regime interdependencies or the core power structures. A more radical shift in the direction of development such as composting of organic household waste thus entails a break from the prevailing development path and the prevailing regime structure, which this path reflects. The organization of such a regime independent development process is recognized to be characterized by high levels of uncertainty as it is not supported by existing institutional arrangements and existing problem solving strategies.

Interactions between reuse initiatives and the waste management regime

If extended product life is to be achieved through new waste management practices, this will require new understandings of when we are managing waste, or managing materials or managing products.

The implementation of the WEEE directive has supported the development of new networks for collecting and treating electronics waste (Lauridsen & Jørgensen, 2010). These are however, all based on massive down cycling through collection, separation and shredding. The EU commission at the time described WEEE as an opportunity for industry to innovate new products, designed for improved disassembly and waste treatment (European Commission, 2002; Hume, Grimes, Jackson & Boyce, 2002). In effect WEEE has supported the expansion of the metal shredding and recycling industry, which has also been supported by the general increase in the price of metals. A fraction of electronic products are reused when they are exported to 3rd world countries. Many of these products are subject to subsequent poor waste handling. The extent of this export is unknown; some estimates are more than 30% (Nordbrand, 2009).

The following section describes how the current Danish waste management regime functions today. We present four examples of the systems responses to new initiatives: (I) A public debate on the need to expand the capacity of the key incineration plant of Copenhagen. (II) The previous organizations of collection of used clothes. (III) The Consumers Councils wishing to extend the guarantee period of larger consumer goods. (IV) The response of the Federation of Danish Industries to the recent spreading of swap sheds and emerging repair facilities at public waste collection sites.

(I) In 2012 it was decided to rebuild and increase the capacity of Amagerforbrændingen, one of the two combined heat and power incineration plants, that burns the waste of Copenhagen and surrounding municipalities.

The decision sparked a public controversy on the waste management system and the impact of increased incineration capacity on reuse and recycling efforts. NGO groups introduced new technologies for waste separation – especially on the household waste – as an alternative. Although political goals to lower the amounts of incineration of unsorted waste were well established, these goals were never influential on the decision to build new ovens with an increased capacity. An existing network of incinerator manufacturers, engineers working with combined heat and power, and consultants were able to produce a very strong report on the economy of the new facility with reference to existing calculative practices and similar technical solutions. The alternative description of the advantages of new waste sorting and recycling technologies was in comparison based on a lot of assumptions. Faced with the challenge of making a choice that involved 500 million Euro, the board of the incineration plant considered, that there was too much insecurity involved with a new technology path, and hence decided to build a new plant with a capacity which is a linear progression of the increase of waste in recent years.

(II) There are many new initiatives concerning the reuse of clothes. For many years it has been an existing practice of NGO's to collect used clothes in containers placed both in the public space for examples in parking lots near supermarkets but also in the public waste collection centres. Some of these clothes are resold in second-hand shops, but the vast majority is exported for use in the 3rd world. Independent of this a large-scale commercial clothing retail chain has launched an initiative, where the customer is encouraged to take back old, used items for material re-cycling in return for a small gift-certificate offering a 15% discount on one piece of new clothes. Concerning clothes that are actually reused in the Danish context, the Danish Fashion Institute last year launched an annual public 'swapping-market' during the Danish Fashion Week. Other initiatives are organized clothes swapping and clothing-libraries such as Share Your Closet where subscribers contribute to a shared virtual wardrobe. Recently the City of Copenhagen has announced that it has agreed to organize a more comprehensive collection of clothes together with the clothing sector and NGOs. It is still unclear how this system will actually function.

(III) The Danish Consumers Council has repeatedly raised the issue of extending the period of consumer warranty from two to five years on larger consumer goods as for example washing machines. Some consumer-oriented politicians are now in support of this, but the Danish Trade Association has voiced an explicit critique of such initiatives. It will, according to them, only lead to more expensive products because shops will be required to stock large inventories of repair material. Clearly a requirement of a five-year lifetime will be easier for some manufacturers than others, and there will be a change in the set-up of the market. Selling products with a five-year warranty may require not only products with an improved quality and lifetime, but also an organization where there is increased need of competences to service products and maintain customer relationships. These competences are very far from the core business model of the domestic appliance outlets that dominate the market today.

(IV) Swap sheds and repair facilities are now spreading rapidly in Denmark. The most prominent examples are in Næstved, Hjørring and Sønderborg. In Næstved the workers at the public waste collection facility actively engage with the public when they come with reusable items. Before throwing them in the container, the public is asked to reconsider their waste as potentially reusable products and hand them over to the workers, who will take them to the swap shop. The swap shop includes easy repair facilities and a very popular outlet, where recycled products can be bought cheap. The swap shops have a relatively low but rapidly increasing turnover in 2014 (approximately 30.000 €/year), and new swap shops are now opening up at many waste management facilities following the examples of Næstved, Hjørring and Sønderborg. Customer surveys indicate that product swaps may substitute as much as 70% new goods (Johansen, 2014). The initiative in Næstved is locally considered to be both a product reuse and an employment initiative providing jobs to a provincial area, where there is a relatively high rate of unemployment. Interestingly, the most developed examples of waste reuse in Næstved, Hjørring and Sønderborg are all peripheral municipalities on with high unemployment rates.

In February 2015 the Federation of Danish Industries (DI) made a formal complaint about the legality of swap-sheds, outlets and repair-shops (DI, 2015). DI complains about the public being asked at the waste facility to consider their waste as reusable products. According to DI the public waste collection centres are obliged to let the waste they receive be subject to 'waste treatment' especially concerning the WEEE waste. It is still unclear what impact this complaint will have but it is clear that definitions of waste and waste treatment for reuse and recycling are at stake. Clearly the reuse activities have now reached a level, where they are considered a potential threat by the established materials recycling industry.

Discussion and conclusions

There is a strong current waste manage regime which is dominated by incineration practice. The big incineration plants operate as publicly owned companies, which are technically aligned with systems providing district heat and electric power. All households are obliged to have their waste collected by these companies. There are similarities with regards to how the different fractions are managed but also differences. There is for example a longstanding tradition for the collection and distribution of used clothes by charity organisations. It has never been questioned whether charity organisations such as the Red Cross should be allowed to collect and resell clothes. On the other hand they have also never really challenged the existing institutions such as the market of new clothes.

When The Federation of Danish Industries objects to whether waste facility workers can ask the public to donate their products to reuse, it is also a question of product ownership. Who can decide what should happen to the product once the previous owner leaves it? The WEEE directive stipulates that the electronics industry must set up collection systems for waste electronics. But if products can be reused they are not waste and should accordingly not be left to a collection system, which treats the products as a mixed materials stream and hence applies a number of separation processes to it. What is the legislative implication of the waste hierarchy, and can it support to establish that 'proper waste treatment' can also be product refurbishment and reuse?

Critique of incineration as the dominant type of waste recycling has together with increasing material prices and increased political awareness of the availability of scarce resources (metals) led to an increased focus of waste as material streams. The parallel liberalisation of the waste management has led to the development of new commercial and industrial networks of waste separation, material sorting and material recycling. These networks constitute strong path dependencies in the waste management regime, and they actively try to resist new initiatives of direct product reuse.

Incineration facilities are changing their identity to resource centres and energy providers. Surprisingly, there are also many experiments within these organizations to not only burn the waste but also to improve the separation of materials for recycling and even preparing waste products to be resold and used again. This is most prevalent in the peripheral parts of Denmark, where public reuse initiatives are closely linked to employment policy. Creation of local jobs has a high priority in these municipalities and job creation may function as a shielding niche where experiments with reuse systems can be developed without competing on the regular market of products and materials.

There are strong policies for improved recycling of materials at both national Danish and transnational EU level. While these policies with notions such as material circularity may function to stress the current incineration dominated waste management regime, they do not by themselves provide reconfiguration of the current waste management networks. Rather alternative networks related to employment policy appear to be productive in providing alternative setups that can stimulate reuse of increasing quantities of products.

In order to improve the possibilities of extending product lives, it is necessary to also address the situation where products are discarded and become waste to the consumer. Waste management is a heavily institutionalized field and consumers' behaviours with waste are strongly influenced by deep-rooted practices. Extending product life thus touches upon the interplay of multiple regimes: waste management, heating, electricity, and materials (metals) recycling.

Swap initiatives only have a limited impact as mediators of transformative change when are decoupled from the existing waste management system. However, refurbishment and swap initiatives as niche initiatives may develop into wider accepted practices if they succeed in linking up with the established waste management system. This interlinking may literally take place by setting up repair workshops at local waste collection facilities. But also social and institutional links are important. Attempts to frame new product reuse initiatives, as elements in employment policies appears to be a promising option for the further development.

Clearly there will be no transformation of the waste system by just demonstrating that many products are still functioning or easily refurbished to become functioning again. As isolated elements refurbishment initiatives are not strong transition mediators today. The current waste management system treats all waste as material stream and is as such not disinterested in products and functional entities. Rather, extended product life by reuse and refurbishment will require new cognitive framings, institutional frameworks and social practices that engage with used products in order to save them from ending up as material streams.

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Cosmetic wear and affective responses in digital products: towards an understanding of what types of cosmetic wear cause what types of attitudinal responses from smartphone users

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Keywords: emotional durability; wear; tribology; product obsolescence; attitudinal response.

Abstract: The manufacture of electronic consumer goods involves the consumption of a variety of materials. The outer skins of electronic goods are commonly manufactured using materials such as metal, plastic and glass. These types of materials, however, are being disposed of in landfill and are not being recycled, despite the introduction of the WEEE directive in 2012 (Waste Electrical and Electronic Equipment (DIRECTIVE 2012/19/EU, 2012)). Calculations by the Industry Council for Electronic Equipment Recycling (ICER), estimate that the amount of electronic products that are making their way into landfill is around 1 million tonnes a year in England alone (ICER, 2005).

These skin materials and the attitudinal responses that users have when they reflect on cosmetic change, is the focus for the study that is detailed within this paper. The study is part of wider doctoral research where the aim is to identify if cosmetic changes in digital products alter replacement behaviours and product attachment. This is the first study to look at the affective material changes that occur on electronic devices and it is the first to elucidate a taxonomy of damage (TOD) which describes the variety of damage that occurs during the use phase of an electronic device. The second part of the study is an analysis of how these material changes affect the attitudinal responses of users and as such is retrospective.

Introduction

Cosmetic obsolescence has been seen to take place in textiles (worn in jeans (Burns, 2010)), ceramics (stain ceramics (Wood, 2008) and furniture (patina accumulating on wooden furniture (van Nes et al., 1999)). Chapman identifies this when considering patina and states that: "*patina is a necessary design consideration to assist the extension of product life spans in graceful and socially acceptable ways.*" (2014, pp.141).

Chapman uses an example in digital products, where he states that they "*tend to occupy a synthetic and scratch-free world of slick polymers…*" (2014, pp.141). If the concept of scratch-free materials is synonymous with digital products, there is an implication that the materials that are used in analogue products are, given societal and semantic norms, more accepting of wear. The classic examples of leather and wooden goods are often used to illustrate this (Wooley, 2003; Rognoli & Karana, 2014). It is interesting to note here that the distinction between analogue and digital products and between natural and man-made materials may provide us with a link between the product type and the material; i.e. analogue products age well because they are made of natural materials – digital products age badly because they are made of man-made materials. In the case of digital products, this is argued within the literature (Fisher; 2004, Odom & Pierce; 2009) as it is posited that wear has a detrimental effect on the appreciation of the materials when they are used in the outer casings of digital products. In terms of analogue products, this is also advocated by a disparate selection of literature that suggests that the properties of ceramics, leather and wood, for example, lend themselves to being imbued with meaning, personal stories and a preferential cosmetic look and feel (Rognoli & Karana, 2014). There are far fewer examples of digital products being considered in terms of wear and material changes but the examples that do exist suggest that digital products that are skinned with man-made materials are less likely to acquire a meaningful patina. This is shown in Odom and Pierce (2009) and Odom, Pierce, Stolterman and Blevis (2009) who found that accumulation of wear had a negative effect on the user perceptions of products. It can be seen that the '*wear*' that accumulates on an electronic product has a detrimental effect to the overall appearance and that the concept of '*clean*' and '*new*' is a material state that is deemed as advantageous to have (van Nes et al., 1999; Fisher, 2008; Burns, 2010).

If '*newness*' and '*cleanliness*' of an object is regarded as an important material characteristic, it follows that it must be an important factor outside that of practical function, therefore falling within the remit of cosmetic obsolescence (cosmetic obsolescence here being distinguished apart from aesthetic obsolescence as it is only concerned with the visual and physical characteristics of an object and not associated trends of fashion (van Nes et al., 1999).)

Methods

The data collection consisted of two separate but linked studies. Study 1 was a cataloguing of the types of material change (MC) that has occurred on a set of 50 mobile phones, which belonged to undergraduate students between the ages of 18 and 25. The cataloguing consisted of a photographic record being taken of the participants devices with the MC being recorded during the photography process and also through retrospective image analysis. This ensured that all of the MC's had been recorded and documented. The MC's were documented by the identification of the following tribology (the science of interacting surfaces and resultant wear) descriptors: *Abrasion* (the rubbing or scratching of a surface), *Ablation* (the removal or chipping away of material from a surface) and *Impact* (the deformation or change in form of a material due to physical contact with another material). *Accumulated Dirt* was also included as a measure of wear due to it being present in a significant number of product appraisals. These tribology indicators make up the taxonomy of damage (TOD) for this product family.

Study 2, which consisted of the interview, was split into three stages where the participants were asked to identify all the MC's that had occurred during their period of ownership, to recollect where and how the MC had occurred in each case and finally to compare how they would have felt if the MC had occurred closer to the beginning or later on in their period of ownership (comparing new and old damage dependent on what the MC was). The interviews were then transcribed verbatim by the researcher, coded and thematically analysed to elucidate the relationship between types of MC, attitudinal reaction and time of MC during product ownership.

The participants for the studies were selected using purposive sampling, which Robson describes as "*the principle of selection…is the researcher's judgment as to the typicality or interest*" (2011, p.274). The sample was selected from UK nationals between the ages of 18-25 as they represented the highest consumption rate of mobile phones (Smith, 2010).

Loughborough University students who were engaged in the first year undergraduate degree module 'Industrial Design Studies 1' (IDS1) were highlighted as a set of potential participants due to their availability and flexibility. Study 1 also required the participant number to be at least 50 (so that statistical significance could be achieved, (Robson, 2011)). The student body in IDS1 was in excess of 120 students which allowed a good opportunity to recruit the minimum 50 required participants.

The participants took part in a seminar group on a Friday afternoon between 13:00 and 15:00. This enabled Study 1 to engage with the whole group rather than attempt to invite them to take part outside of class and on an individual basis, which may have proved logistically more difficult and time consuming.

After Study 1, participants were asked to sign up in principle for the follow up interview in Study 2. Of the 37 participants that signed up, 12 respondents were available for the second part of the study, thus making the cohort for Study 2, self-selecting. The 12 participants that took part in the second stage of the study also represented a homogenised population (Guest et al, 2006) and as such represented a numerically significant cohort for conclusions to be elucidated from.

Results

The results section will be split into Study 1 and Study 2, which reflect on the research aims of both studies.

Results Part A – Material Change Analysis

From the identification of the types of MC that have occurred on the 50 devices, it can be seen that Abrasion was the most common MC with it occurring in 68% of the participants devices. Impact was seen in 50% of the devices that were looked at. Accumulated Dirt occurred in 36% of the phones and Ablation occurred in 30% of the devices.

A selection of the typical images collected for each of the MC's can be seen in Figure 1.

The spread of the types of MC over self-reported periods of ownership indicated a correlation between the gradual increase of MC and length of ownership, which was as expected with devices that were being owned for longer periods of time (see Figure 2). It was interesting to note, however, that the 8% of devices that had no damage recorded were also used *without* any protective products such as cases or screen protectors.

During Study 1 it was found that there were a significant proportion of devices that were being used that had an instance of wear on them (92%). Impact damage predominantly occurred (or originated from) on the corners of the phone and resulted in cracks, separation of material and splits in the screen component.

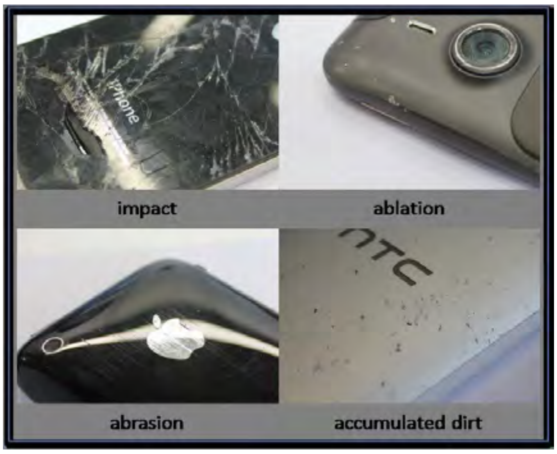

Figure 1. Examples of material changes based on tribology indicators. Source: Authors own images.

The same location on the device across the sample (the corners) saw the majority of instances of ablation where material had been chipped from the surface and material had been deformed or removed. Abrasion occurred on most parts of the phone but due to the definition of Abrasion including scratching and rubbing, there were significant instances of scratching on the flat areas on the back and front of the phones, and rubbing which mainly occurred on the edges and corners.

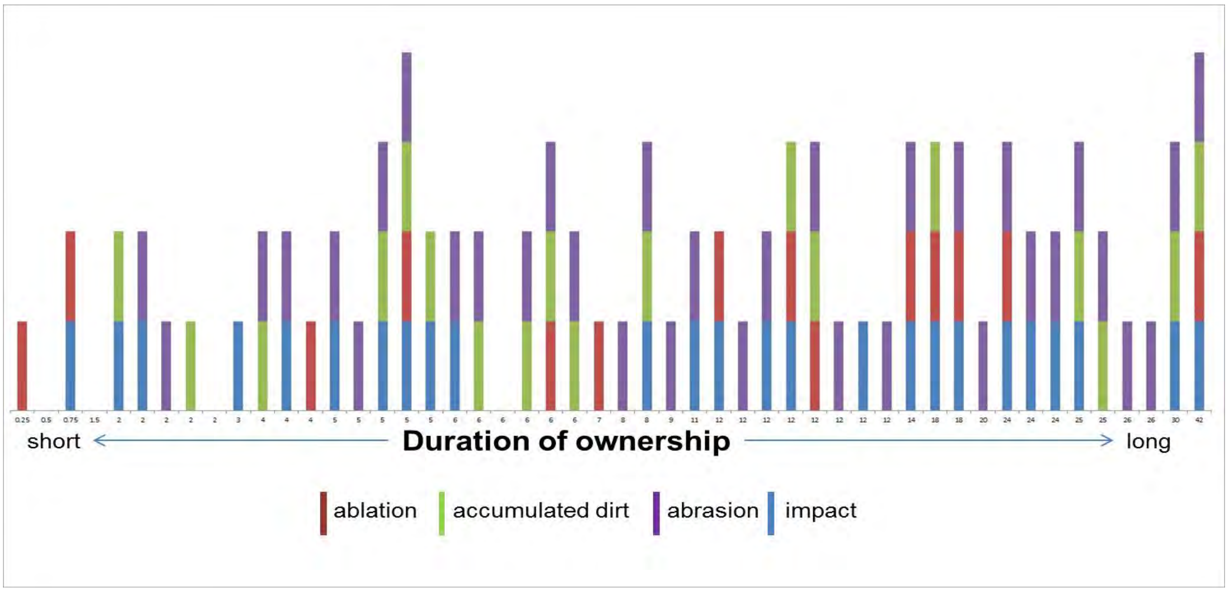

Figure 2. Accumulation of wear across participants (n=50).

Accumulated Dirt was found to be common on the phones that had been kept in cases and where there were indentations or ridges in the exterior of the phone into which dirt could accumulate and be prevented from being removed during regular use; i.e. physical switches, recesses and joins in the material components.

Each phone was attributed with a Cumulative Damage Score (CDS) which corresponded with an overall assessment of the wear. If a phone had only one instance of Ablation, for example, it scored 1 on the CDS. If it had Ablation and Abrasion, it scored 2; and so on until the maximum CDS score achievable was 4, given that the phone exhibited all types of wear. Figure 3 illustrates the instances of CDS scores across the cohort number.

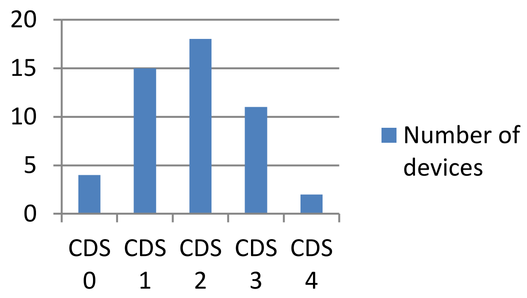

Figure 3. Cumulative Damage Score across devices

The CDS did not include an assessment of the severity or variability of the wear. For example, if a phone had one scratch or many, it was given 1 mark on the CDS. This is an issue that needs to be addressed in further iterations of the study. There was also seen to be a relationship between the uptake of protective devices and the damage that was occurring on the phones (see Figure 4). There was an interesting difference between the start, middle and end stages of use and when the protective devices were being adopted, indicating that the protective devices were being used less in the initial and end stages of use and the uptake of their use was in reaction to damage occurring at the preliminary stages of ownership.

Results Part B– Qualitative Interviews

From the qualitative interviews, which followed the visual inspection of the devices in Study 1, the participants reflected on incidents of MC that had occurred on their devices since the beginning of ownership. In the majority, participants reflected that if the MC that was being discussed (which was conducted for each example of MC on their device) had occurred in the early period of ownership, their attitudinal reaction would have been more negative. For example Participant (P)1 stated that on reflecting whether an impact MC which was evident on the back of their phone had occurred within the first month of ownership, "[I would have been] *more annoyed, I would have probably got it fixed.*" This is supported by a comment by P2, "*that would annoy me, yeah you kind of expect things to be tougher than that*". This was a common occurring response

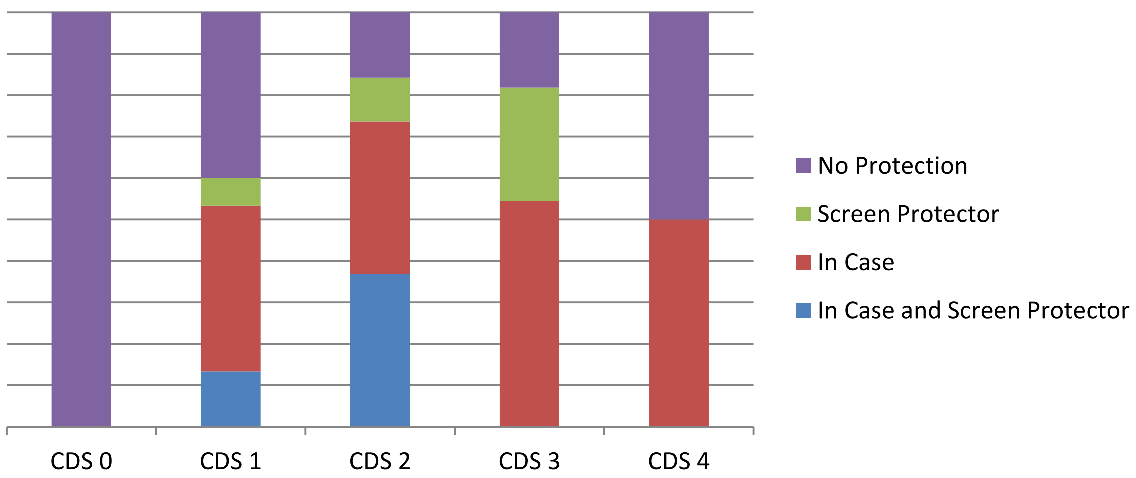

Figure 4. Cumulative Damage Score and uptake of protective products.

to any MC that had occurred on the participants devices. Annoyance of the expected build quality of the device at an early stage seems to be an overriding factor.

Reflections on the physical changes

The participant's attitude towards the types of damage on their devices ranged from '*non-plus*' to '*annoyance*'. Responses were often influenced by the working condition of their phones; if the device still functioned as desired then the damage was not seen to be as bad. However, there were some differences in response to when and where wear occurred on the phones.

Damage occurring earlier on in ownership is seen as more annoying and elicits more attitudinal reaction. The point at which the first instance of damage occurs, the level of tolerance increases towards the subsequent instances of damage that occur. The results indicate that there was a moment of relief in being able to use the product without restraint after the first significant piece of wear had occurred. P2 stated *"...I'm pretty protective over it for the first couple of weeks and then after that you don't really notice damage so much.*" which is supported by P6 who stated "*when it's new you're like it's fresh and stuff but if you've had it six months, it becomes just part of the furniture.*" There was a noticeable difference between responses depending on whether the phone was new or not new. As P7 stated "*Obviously when you first get it* [wear occurring] *you're really sad, because you're like 'oh my god it's new' but now it's just like 'what else is new?'*". This tipping point of '*care*' was seen to occur either after a significant first instance of wear or after a period of time when the novelty of a new device had worn off. The duration for the period of novelty are different for each participant but a '*few months*' was a common response when prompted by the interviewer.

What if...reflections

It was identified that if participant devices had received the same damage at the beginning of ownership then the reactions would have been more extreme. When asked if the most prominent type of damage on their phone had occurred at the start of their ownership, P4 stated "*I think I would have been more annoyed.*". P9 supported this by stating that "[I] *think I'd be more annoyed about it, if it had happened straight away*". The reaction to the fictional scenario of the wear occurring at the start of ownership also elicited disappointment in the construction of the devices; P2 explained "*that would annoy me, yeah you kind of expect things to be tougher than that.*".
This scenario also prompted respondents to talk about services in which phones are covered for damage. The safety net of insurance, warranties, and new phones with upgrades meant that some damage was excused or ignored, especially if it occurred at the end of a contract. P8 was '*due*' a new phone on their contract and therefore responded with "*oh well, I'll change it in two months' time*"; identifying the influence of the contract system of upgrades and new devices. This apathy for the wear that was occurring was reiterated by the fact that some of the devices were not bought by the participants, as P11 confirmed "*I'm not in the least bit bothered, because I didn't buy the phone*". This indicated a detachment to the condition of the phone, illustrating a symptom of the purchasing structure that accompanies phones and the lack of an upfront monetary commitment.

It was seen that a certain severity of damage is expected nearer to the end of contracts thus attitudinal responses to wear was less with promise of a new device in the near future. Overall, there was an indication that damage occurring at the start of a contract was deemed worse than damage at the end. The assessment of the damage was often justified by the opportunity to upgrade in the near future or the fact that the phone still functioned despite the cosmetic damage and therefore was not an issue, however this was often stated with the caveat that they did "*need a new phone*" or a "*new device would be nice*" (stated by P7).

The importance of performance

A significant amount of respondents' reaction to the types of cosmetic damage that was occurring was justified by the disclaimer that "*as long as it doesn't affect how the phone works it doesn't bother me*" (P11). Given the access that a smartphone provides to the user, the requirement to make calls, send texts, access social networks, capture and share images of everyday life; the necessity of functioning software seems to increase user tolerance for cosmetic damage.

Practical function of the software was also seen as important as the necessity to have an electronic product that retains battery life, maintains processing speed and can be upgraded to compare with contemporary models; are all contributing factors to the users ongoing assessment of a digital product like a smartphone.

Discussion

The study provides evidence that there is a relationship between material changes and the user's attitudinal response to them depending on when they occur during a period of ownership and where they appear on the device itself.

The link between these attitudinal responses and the impact these have in the replacement behaviours of users' needs to be addressed and elucidated in further studies, however, even with this preliminary and exploratory study it can be seen that it could be a contributory element in replacement behaviour. A proposal for the relationship between the necessity of a digital product to function, the appreciation of newness and the tolerance of wear can be seen in Figure 5. This hypothesis will be tested in a further longitudinal study that will track ageing of digital devices and the extension of study 1 and study 2 with three other product categories (over-ear headphones, tablet pc and fitness tracker bands).

From these two exploratory studies it could be hypothesised that there is a constant level of need for physical function. Responses from Study 2 indicate this to be the case, and that functional obsolescence is a more important decision making factor than the negativity of wear occurring and cosmetic obsolescence (i.e. '*as long as it still works, I don't mind how it looks*'). This reinforces Fisher (2004) and Odom & Pierce (2009) when they refer to the lack of appreciation of ageing plastics and the importance of content rather than product.

In the hypothesis, as length of ownership increased, tolerance of wear over time goes up. The rate at which this tolerance increases is subject to noticeable and significant wear occurring at different points along the length of ownership. If this happens earlier in ownership then the levels of tolerance of wear increases above that of the normal rate. Counter to this, there is an opposing reduction in the appreciation of the newness of a new device where a '*honeymoon*' period of ownership is observed, making wear less acceptable and less tolerated. This again can decline quicker with more rapid accumulation of wear on a device occurring earlier in a period of ownership. The rate of tolerance has not been investigated in the literature so far and would contribute to a new understanding of how cosmetic changes contribute to product replacement. It would also go towards explaining why and in what ways the wear that accumulates on digital devices is not appreciated.

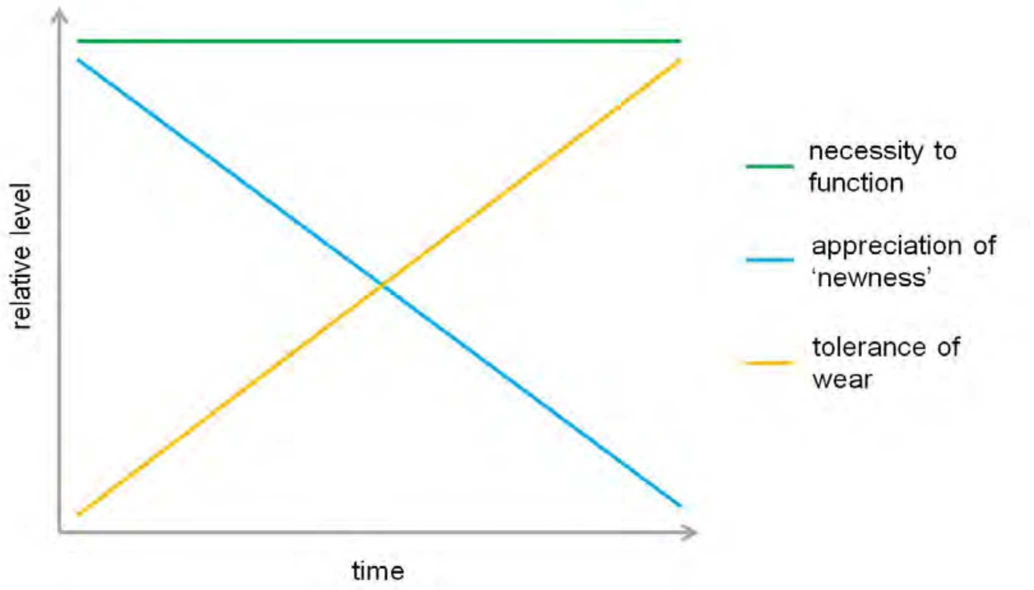

Figure 5. Hypothesis of the relationship between function, newness and wear.

The amount to which material changes contribute to product replacement will be explored in further studies which repeat the method outlined in this paper using different product families, in addition to conducting a third, longitudinal study which will seek to track the material changes and the attitudes towards those changes in real time to observe and to understand if they are contributing to an increased tendency towards replacement.

Conclusions

The user's tolerance of wear in smartphones is very low at the start of ownership due to products being '*new*' and wear being more easily identifiable. After the first instance of wear occurring, the tolerance level for wear increases and the accumulation of more instances of wear does not elicit as much of a negative attitudinal reaction. The findings show that Impact and Ablation are the least tolerated types of wear, due to the fact they are often the result of accidental damage, such as dropping the device. Accumulated Dirt is incremental and takes longer to accumulate on a device, hence not eliciting as much of a reaction. Abrasion was also seen as more tolerable as scratches were expected with use and again are more noticeable over longer periods of time.

There was no noticeable pattern with specific MC's occurring at particular times, although Accumulated Dirt was seen to increase over time. The MC's did occur on specific parts of the device with damage to the screen/front being seen as the most affective. This leads us to propose that even though there is not a predictable pattern of wear occurring on smartphones, the times at which they happen across a period of ownership, the likelihood of them appearing on prominent areas of the device and the type of wear that is occurring, can influence attitudes towards the appreciation of participants' devices.

Due to the social access granted by smartphone devices (social networking, calls, texts etc.), product performance and stability was dictated largely by the software. The internal hardware (such as battery life and processor speed) was also seen as an important factor in participants' appraisal of how the product was ageing. The external '*skin*' of the product was seen to be less of a concern.

In conclusion, the types of wear that presently accumulate on the outer-skin of a product are not desirable. Rarely was the accumulation of wear seen as beneficial or aesthetically pleasing, our results confirming the literature on the subject. Over time the tolerance for cosmetic wear increases and priority switches from aesthetics to function. Within the category of smartphones the necessity for stable functionality is paramount, wear and tear is expected, and access to networks is more important than the device that provides it.

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Sustainable design: the durability of design classics as a stimulus to reduce the environmental impact of products

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Keywords: sustainable design; environmental impacts; eco-design strategies; design for longevity; design classics.

Abstract: This research identifies the process of the study that focuses on durability as a strategy for the prevention/reduction of environmental impacts caused by the production and consumption of Western societies. The study was first based on collecting issues to justify the need for the research. Through knowledge about the consequences of premature disposal of products, including the production of waste and use of resources, the research was directed to strategies that motivate consumption reduction by increasing the product's life. The durability of some products referred to as Design Classics was the trigger for the research. After defining the universe that fits this category, a selection of samples considered representative was made and a database with systematized content for research was made. Through the qualitative and quantitative analysis of these samples, we obtained a standard model that enabled us to set a strategy for designing products with a relatively greater useful life. The results of the implementation of this strategy for future manufacturing of artefacts will be presented to our national industry.

Introduction

Strategies and tools have been developed to integrate eco-design or design procedures addressing environmental concerns. This paper describes the on-going research that aims to contribute to the development of an eco-design strategy-"Design for longevity", to increase product life and reduce environmental impacts mainly due to obsolescence. Motivated by the environmental consequences of excessive consumption of natural resources, energy and disposability of products, the research was focused on the product system level, which includes the optimization of initial lifetime and more precisely the optimization of mechanisms that enable the reduction of environmental impacts by consumption reduction. Design for longevity aims to extend the product's useful life, its technical, functional and aesthetic qualities, i.e. the time that the product functions correctly and the time the user finds the product attractive. This implies that objects will be used for longer periods of time, postponing the need for premature replacement, minimizing resources and environmental impacts. However, we are aware that a shorter life is preferable if a new, more energy-efficient and less resource-consuming product is a natural choice. For this strategy, designers should know design principles described in the literature that may be considered during the product design development. In this context, we investigated issues and reasons that lead to obsolescence of products and acquired the necessary comprehension about exceptional industrial products (timeless design) based on durability concepts defined in the literature as Design Classics, Icons and Cult objects. Through the characteristics of each we identified the inclusion criteria that characterize and define the boundaries of the universe of elements that were needed for our investigation. The Design Classics which are products that remain in production for several generations despite the production of new versions and changes in fashion, taste and cultural changes were the ones chosen.

Motivations for research

We are becoming increasingly conscious that our planet will not cope with many more years of intensive use, as happened in the twentieth century. Faced with this undeniable fact, an important question is how to invert this situation and simultaneously satisfy our daily needs and aspirations without jeopardizing the needs of future generations. Researchers and various organizations have appealed to the responsibility of manufacturers and consumers calling for an urgent change in behaviour. Design can play an important role in defining more sustainable solutions that can allow us to live consciously better, consuming less and regenerating our physical and social environment considering ethical principles.

Concerning the practical results, we are able to show a model for the development of products with low environmental impact based on the theoretical hypothesis that long-lasting products will be better for the environment. Increased durability and consequent extension of useful life can contribute to diminishing impacts caused by premature elimination (waste production) and production of new artefacts (consumption of raw material and energy).

Research

The reasons leading to product elimination are several: properties' degradation or structural fatigue caused by intensive use; chemical or natural degradation; damage caused by accidents through improper use; technological obsolescence of products that incorporate mechanical or electronic devices which are frequently updated, and cultural and aesthetic obsolescence for fashion products (Kazazian, 2005; Lewis & Gertsakis, 2001). Programmed or planned obsolescence implies the design of products or components to have a shortened useful lifespan by manipulating their durability characteristics (Fiell & Fiell, 2000). "Relative obsolescence", including the disposal of products that still work adequately at the time of alienation and "absolute obsolescence", concerning the disposal of products due to damage, are designations also used to characterize the processes through which products are transformed into waste (Cooper, 2004). This waste has three major destinations: recycling, landfill or incineration.

The "European Waste Hierarchy" expressed in Directive 2008/98/EC on waste (European Parliament and Council, 2008) which defines 5 actions/ solutions:

1. Waste prevention
2. Reuse and preparation for reuse
3. Recycling
4. Recovery (including energetic valorisation)/ incineration
5. Disposal (safe storage/landfill).

This work intends to present contributions at the first level, defined as a set of measures taken to avoid a substance, material or product becoming waste (European Parliament and Council, 2008). In this sense, and in the scope of this investigation, extending products' useful life is an encouraging factor to reduce consumption.

According to the literature review, different design strategies present effects in different phases of the whole product life-cycle, from extraction and processing of raw materials to its elimination. Together with the so-called Eco-design strategies described in the bibliography (Fuad-Luke, 2004; Hemel, 1998; Lewis & Gertsakis, 2001; Lindbeck & Wygant, 1995; Manzini & Vezzoli, 2002; Tischner, 2001; Yeang & Woo, 2010), "extending products' useful life" or "design for longevity" is one of those approaching objectively the issue of durability. The aim of this strategy is to extend the product's useful life in its technical and aesthetic qualities. This implies that products will be used for a longer period of time.

There are at least two ways to optimize products' useful life: increasing product durability or intensification of use. The design concepts associated with these types of possibilities are various and range from multi-functionality and modularity to personalization, adaptability, easy repair, and maintenance or possibility of re-use. However, investigation has focused on the principle of "how to reach a classic design" (Hemel, 1998), "considering classic design" (Lewis & Gertsakis, 2001) or seeking greater product longevity through "timeless design" (Tischner, 2001).

Aims and questions of the research

The following initial research questions were elaborated:

Does the status of Design Classic "obtained" by some products depend to a great extent on a combination of aesthetic, functional and material factors rather than on technological factors?

Can the detailed study of Design Classics be synthesized in a set of product attributes usable in the design process of new products?

Can a design strategy based on characteristics of Design Classics allow the manufacturing of products with the potential for a longer useful life than competing products?

Universe of products and sample constitution

A large variety of consumer products with a relatively long useful life, reputation or importance in the industrial design field are portrayed in different publications such as exhibition catalogues, monographs and within a variety of work joining a wide range of objects. Selection of this set of objects for collections, publications or exhibitions is due to the acclaim of academics, critics, historians, curators, journalists, designers and architects who consider them exceptional (Julier, 1993; Phaidon Press, 2006; Pile, 1994).

In the literature we can find various terminologies that are generally used to define a range of products considered exceptions. For example, in the "This is Design" exhibition of the Design Museum (2011) we can find designations like icons of Design (Albus, Kras & Woodham, 2004; Parra, 2009), Cult Objects (Sudjic, 1985), Marvels of Design (Antonelli, 2005), The Genius of Design (Sparke, 2009), Objects of Desire (Forty, 1986), Design of the Times (Bhaskaran, 2005). These titles include not only products that stand out through having a long useful life and still being in production. In fact, for different reasons, other products belong to the history of product design: objects of devotion or veneration reflecting the style preferences of a certain group or sector of society; objects that go beyond their usefulness and reach greater recognition; objects that cause social changes; objects that give their users more quality of life; or small objects we use every day without realizing how important they are in our daily life. The Design Classic (Clay, 2009; Gay, Camden Arts Centre & Arkwright Arts Trust, 1977; Julier, 1993, 2008; McDermott, 2002, 2007; Phaidon Press, 2006; Pile, 1994) can be defined as a mass-produced product of aesthetic value and lasting quality which stands out because of its timeless influence and lasting significance, and which is innovative in integrating new materials while remaining unchanged since its creation (Phaidon Press, 2006). Another approach goes further, stating that classics are objects which due to the quality of their design remain practically unaltered and in production for more than 25 years (Parra, 2009). Other authors (Clay, 2009; Pile, 1994) also refer to timeless quality. Transcending changes in taste and fashion give these products a lasting quality (Julier, 1993; McDermott, 2007). Fascination with the long and useful life of some objects was also at the origin of the collection of monographs dedicated to Design Classics, edited by Volker Fischer and published by Forum Verlag in 1999. Various authors (Botsch, 1999; Droste, 1999; Irrek, 1999; Klemp, 1999; Mende, 1999) describe products which, according to the editor, established standards of form, function and brand communication. Older references to Design Classics appeared in two exhibitions in London, United Kingdom, "Classics of Modern Design" (1977) and "Classics" (Heal & Ltd, 1981), events that reflected the desire for a standard of formally approved and historically irreproachable models (Jervis, 1984). The Museum of Modern Art in New York has been most influential in establishing what is a Classic (Jervis, 1984; Julier,1997).

The knowledge obtained from the literature review of exceptional industrial products allowed us to select inclusion criteria that characterize the universe of products (Design Classics) considering the main objective of the investigation. The first criterion is concerned with the year from which we should include and consider these products. Considering that "... industrial design is born from technological development, i.e., without the possibility to offer the machines to mass produce, we could not speak of industrial products and design." (Torrent & Marín, 2009). We considered the beginning of the Industrial Revolution as the starting point, and the year of 1760 is generally accepted. The second criterion used is the minimum lifetime to be considered as a durable product. For this point we consider the previous reference to the same product being used for generations. The Oxford Advanced Learner's dictionary defines the term generation as "the average time in which children grow up, become adults and have their own children (generally considered about 30 years). Thus, for a product manufactured in 2012 to be considered as belonging to the universe of products studied, it must be in current production (as a Design Classic) and have been produced in the period of three consecutive generations or more than 90 years, 1922-1952; 1952-1982 and 1982-2012 , because the resumption of its production/editing in a more recent decade may be due to fashion, which seems to be the case with some objects designed by the Swedish designer Greta Magnusson Grossman (1906-1999) and produced by the Danish company Gubi (SUQI, 2011).

Briefly, we decided that products belonging to the universe of Design Classics should meet the following criteria:

- Durable, non-disposable consumer goods
- Industrially mass-produced
- Non-technical/professional
- Manufactured currently with the name of the manufacturer
- Produced/commercialized in the period corresponding to three consecutive generations including the current one (1923-2012)
- Currently in production (2012)
- Keeps the original design and may have undergone some updates in order to improve safety, production efficiency and reduce environmental impacts
- Published in the literature of reference
- With creation date, known author and information about the history of production.

Since we observed a large number of disperse elements belonging to that universe, it was necessary to select a relatively small set of representative products (sample) and the results obtained can be statistically generalized to the entire target population with an adequate margin of error. Through document analysis, it was possible to study this sample and characterize the objects (products) and their authors. Considering the criteria proposed above, we selected a sample of 100 products described in Phaidon Design Classics (2006) that were also described by several authors (Julier, 1993; McDermott, 1999; Albus, Kras & Woodham, 2004; Antonelli, 2005; Polster, 2008; Morteo, 2009; Sparke, 2009). For this study we used the document analysis technique, where written sources were the basis of the research focused on contemporary or retrospective documents with information considered reliable and valid for the study.

Instrument of data collection

To facilitate data analysis, a data-collecting tool was built to provide information about the set of products selected and under study. The instrument/table was separated into several columns (title, year of creation, country of origin, author's name, author's date of birth, author's nationality, author's profession, components, materials, dimensions, function, colours, shapes, manufacturers, weight, price and the words that describe the product) destined to characterize the sample of Design Classics. The set of criteria gathered was based on the Portuguese standard NP 405 (1998), which specifies the elements of references regarding objects: "Three-dimensional artefact".

Results

The results revealed that Design Classics include a vast number of home products and reinforce the idea that the classification is very frequently associated with furniture (Julier, 1993). Other types of products included are mainly in the categories of cutlery, household iron products, kitchen utensils, ceramics and utility glassware, and lighting articles. At the time of their launch in the market, many of the products listed included innovative materials and manufacturing technologies. Considering form, function and relationship with users, they are characterized by the almost complete absence of decoration, simplicity, functionality, elegance, lightness, sophistication, hardiness, balance, purity, ergonomics, being comfortable, cheap, a prize-winner, popular, flexible and minimalist. No product contains electrical or electronic components, only mechanical ones, and they are made mostly of wood, metal and glass. Most products have been designed in the USA. In Europe, products come mainly from six countries: Germany, France, England, Denmark, Italy and Finland. Most authors are architects, followed by designers, inventors, and artists from seven countries, namely Germany (the majority), USA, England, Italy, Denmark, France and Finland.

More interesting were the results of the adjectives used to qualify the products of the sample. The 10 most frequently mentioned adjectives were placed in a hierarchy counting the number of times the adjective (or grammatical form which refers to that adjective) was quoted in the documents analysed. The list of 10 adjectives most frequently mentioned is presented below in descending order:

1st. Simple
2nd. Innovative at its time of creation
3rd. Ergonomic
4th. Elegant
5th. Functional
6th. Robust
7th. Economical (Cost)
8th. Variable
9th. Versatile
10th. Combined

Conclusions

The results of the investigation presented instead of trying to produce a definitive explanation, intends to demonstrate that the field is fertilized not only by the consensus that exists among several authors on the recognition of the quality of these exceptional products, but also through the abundance of examples which, despite being "old", are still purchased by consumers. In this scenario, the focus is on building a strategy that can lead to the design of products that include durable characteristics of Design Classics and whose results we can extrapolate for the future. The evaluation of results and verification of the efficiency of the applied strategy will be made through comparison with previously identified case studies, since only time can confirm if new products developed will have a longer lifespan. The research will find fundamentals for the development of new products in the combination of historical and contemporary examples spread over the field of industrial design as a means to find solutions that contribute to building a more sustainable future.

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Reclaimed wood in retail environments: creating an emotional connection for product longevity

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Keywords: sustainable buildings; construction waste reduction; interior finish materials; reclaimed wood; retail design.

Abstract: The building industry is one of the largest product waste contributors with much of this waste generated from interior finish material products. As defined by LEED and other green building standards, a green building project is one that is energy-efficient, water-efficient, and improves indoor air quality and/or engages in material resource conservation. With these guidelines and a desire from designers to create environments that are sustainable but do not compromise aesthetics, many manufactures of interior finish materials have reinvented their product offerings. Though these sustainable design practices have been accepted in certain building segments for quite some time, others such as retail stores are slower to adopt.

As I begin my research, I will be exploring the emotional connection to the finish material itself in an effort to understand how to create product longevity within the built environment. Rather than giving retail stores a face-lift every five to ten years to stay in fashion, I believe that emotionally connecting to the users through thoughtful selection of materials, brands will create a stronger emotional and psychological connection with the users. As such, retail brands will have longer lasting and more sustainable stores. To begin this investigation, I am taking a closer look at the retailers where reclaimed wood products have been implemented into their brand environments. The intent is to initiate a long-range investigation through interviews with designers, retailers, and consumers resulting in the development of case studies around the belief that the emotional connection people have with reclaimed wood products creates longevity for the product within the space and creates a stronger connection to the brand itself.

Introduction

Accounting for nearly 26 percent of non-industrial waste generated in the U.S alone, the building construction industry is one of the largest product waste contributors. Building construction and demolition debris, much of which is from interior finish material products, continues to accumulate in landfills amassing nearly 160 million tons per year. Approximately only 20-30 percent of that construction waste is recovered for recycling. In addition to concrete and metals, wood is one of the leading materials reclaimed for alternative product uses. [1](Environmental Protection Agency, 2009) With the encouragement of sustainable building and material product rating systems such as LEED, Green Globes, Greenguard, and many others, over the last decade designers, architects, and developers have made a concerted effort to change their practice and reduce the environmental impact from the building industry. As defined by LEED and other green building standards, a green building project is one that is energy-efficient, water-efficient, and improves indoor air quality and/or engages in material resource conservation.

With material resource conservation as a contributor to green or sustainable buildings, interior material product manufacturers have made great strides to incorporate recycled, reclaimed, and rapidly renewable content into the materials used within building construction. With these guidelines and a desire from designers to create environments that are sustainable but do not compromise aesthetics, many manufactures of interior finish materials have reinvented their product offerings. As a result, material product manufactures have changed the way they produce their products and redefined the makeup of the product itself. No longer are sustainable buildings considered by the general public to be "granola", but rather seen through the eyes of the users as aesthetically pleasing environments.

In fact the opposite is occurring, there is a desire among building owners to have a stronger connection to the users and communicate a sustainable story. As such, many of the products from the building demolition waste are making their way back into the built environment. One such example is the renovation of an iconic Chicago office tower designed by Mies van de Rohe in 1974. During the renovation of this project, 78 bathrooms were to be demolished and to receive new porcelain tile. Striving to achieve LEED gold, project architects Cannon Design partnered with Crossville, Inc., a porcelain tile product manufacturer, to develop an inspiring idea. They salvaged all of the existing bathroom toilets, lavatories, and tile and turned them into new porcelain tile for the project. Over 200,000 pounds of reclaimed debris was transformed into 57,000 square feet of new tile.[2] (Damon, 2014) This closed loop cycle set a standard for manufacturing and has since allowed Crossville to partner with Toto toilets to recycle their discarded products into new Crossville tiles. This and other projects with similar stories being communicated to the building users allows for the users to have a better understanding of the products being installed in the environments in which they live, work, and shop. Through the stories of these products, users connect on a deep emotional level to the product and the environment in which they are installed.

Another such examples the REI SoHo retail store which will be highlighted as one of the case studies in the paper. As the notion of closing the product loop becomes a desire for sustainability, many designers and owners are looking to incorporate material products that originated from the building site. The REI SoHo store utilizes on-site reclaimed wood materials, which allows for a closed loop product cycle within a retail context.

With an overall perception of sustainability as a desired aesthetic and its story as a connection to its users, this notion has begun to infiltrate some of the slowest segmentations to adopt sustainable design practices. In 2011, according to a study conducted by McGraw-Hill Construction of 79 retailers, 30 hotels, and 22 restaurants, only 18 percent of buildings constructed were considered green. By 2013, this number has grown to 38 percent, more than doubling in only two years. This number is expected to reach 52 percent by 2015.[3] (Bernstein & Russo, 2013)

Sustainable building rating systems continue to drive many of the interior finish manufactures processes to create material products that include recycled, reclaimed, and rapidly renewable content in their products. Products such as rapidly renewable bamboo flooring or a vinyl flooring product that includes rapidly renewable flax seeds are developed and installed to reduce the environmental footprint of the built environment. However, I believe there is more than just a rating system that should be driving these design decisions.

The REI SoHo project in particular has inspired and set the precedent for my belief that the use of reclaimed wood products creates an emotional connection to the built environment and as such the retail brand itself which allows for an extended product life within the built environment. It is this notion that I will begin exploring in this paper and in the outlined trajectory of my research. As I begin my research, I will be exploring the emotional connection to the finish material itself in an effort to understand how to create product longevity within the built environment. Rather than giving retail stores a face-lift every five to ten years to stay in fashion, I believe that through emotionally connecting to the users with thoughtful selection of materials, brands will relate on an emotional and psychological level. As such, retail brands will have longer lasting and more sustainable stores. To begin this investigation, I am taking a closer look at the retailers where reclaimed wood products have been implemented into their brand environments as part of the branded "kit of parts".

Reclaimed wood: an emotional connection

Reclaimed interior finish material products, such as TerraMai's reclaimed wood products, have been installed in inspiring interior spaces for years. Early pioneers in the retail segment who clearly connected the interior finish material product with their brand identity and recognized the connection that their consumers had with the product were brands like Anthropology and Urban Outfitters as well as Starbucks Coffee and Whole Foods Grocery. Over the course of the last three to five years, the implementation of reclaimed wood products has increased dramatically within the retail design segment, specifically within recognized national brands.

Julie Ullrich, a materials expert with 11-plus years specializing in interior finish material products in the retail industry believes that one of the major reasons for this increase is retailers are striving to achieve a perception of sustainability within their consumers. Ullrich states, “Often, the use of reclaimed wood speaks to the individual customer on a personal humanistic level, the product connects to them emotionally and makes the customer feel like the brand is not some large conglomerate but part of their local community. This is seen quite strongly in the strategic design of Starbucks stores.” From our professional experience, Ullrich and I believe that the use of reclaimed wood products not only communicates a connection locally and speaks to sustainability, but it also creates an emotional response that sets the customer at ease. Reclaimed wood is not artificial, it’s genuine, honest and real, and that connects to customers on a human level. Whether conscious or subconscious, the interior material product humanizes the brand and creates a connection between customer, brand, and the natural environment. Ullrich goes on to say, ”Starbucks is a prime example of how reclaimed wood as a finish material product is used to connect the customer to the brand. For years Starbucks has used reclaimed wood at key touch points along the customer’s journey. The customer interacts with the product and it makes them feel connected to the history of the brand, to their philosophy about sustainably and even speaks to their ethics as a company. The single use of the material says so much; it allows the brand to become humanized. It speaks to their neighbourhood approach.”

Kevin Kowal, Regional Director for TerraMai Reclaimed Woods, believes that in addition to the design trend of “localization”, the use of reclaimed wood has become more frequent in retail brands due to four factors: the reduction in cost and becoming more cost competitive; it communicates that the brand cares about the environment and sustainability; the inherent “history” of the product communicates a story about the brand and the material; and it provides and emotional “warmth” that connects to the customer emotionally and creates a sense of permanence.

Kowal notes from his experience “as reclaimed wood products are used within these spaces, the businesses have reduced the frequency and necessity of remodels and have businesses that are continuing to thrive. Despite the recession, reclaimed wood products have continued to be utilised.” I believe, along with Kowal, that the reason behind the longevity of these spaces and thus the longevity of the product is due to the emotional connection people have with reclaimed wood products. With this developing theory, I will be taking a closer look at the retailers where reclaimed wood products have been implemented into the store designs as a major brand component in order to develop a series of case studies that prove this notion.

Creating a case

I will be initiating a long-range investigation to examine the theory that reclaimed wood does indeed connect on an emotional level with consumers, tying them more closely to the retail brand and creating brand loyalty resulting in increased revenue for the brand which in turn creates a longer product life for the interior material itself. Through a series of interviews with retail-focused designers and interior material product experts, national brand retailers, and consumers I will be developing an array of case studies.

Kowal and I have identified four specific brands who have utilized reclaimed wood as a strong brand element within their store environments and whose use of reclaimed wood product emphasizes their brands mission and story: REI Recreational Equipment Incorporated, AT&T, Starbucks Coffee Company, and Lululemon Athletica. In each of these retail brands and store environments, reclaimed wood material products have been identified as part of the brand signature, it is used to communicate a story about the brand mission, evoke a feeling the consumer and to create a connection between the brand, the consumer, and the natural environment.

REI SoHo Flagship, New York City: Immersed in the Brand Story

As New York City continues to transform its urban landscape, infusing more outdoor spaces such as the High Line development, and non-profit groups like Sustainable South Bronx build more urban parks, as well as the ever growing popularity of using bike paths, it's no surprise that outdoor recreation is one of the top retail segments in New York City. Recreation Equipment Incorporated, REI, had been searching for a perfect location to open its doors to New York for many years. The struggle was to find a site that spoke to the company's brand soul and had access to outdoor space. Enter the historic 1885 Puck Building, with 39,000 square feet of space to be transformed from what was once a magazine publishing factory into REI's first New York Store.

In order to transform this historic space into a new and engaging retail store, REI partnered with architecture firm Callison, one of the world's leading retail design firms. In an interview conducted with David Curtis, Associate Principal for Callison New York, he spoke to why the design of the REI store utilized reclaimed wood to connect the brand to the customer. "Reclaimed wood is an important component of sustainability. One of our major design principles for the REI project was reusing as much of the existing material on site as possible, as well as repurposing material. In areas where this was not possible, we wanted to specify items such as reclaimed wood for the flooring to be consistent with these principles. REI prides itself on their environmentally friendly practices and reclaimed wood fits into this ethos. REI's customer base is very much aligned with the company brand. The REI mission statement "Our core purpose is to inspire, educate and outfit people for a lifetime of outdoor adventure and stewardship" goes right to the heart of those customers."

In approaching the redesign, Callison teamed up with TerraMai to reclaim as much from the original 1885 building as possible, salvaging existing wood elements and transforming them into new design features for the store experience. Extracting everything from the original wood flooring, wood panelling, and even floor joists, TerraMai hulled away the 125-year-old material and re-milled it into new product to be installed in the redesign. Carving a large atrium into the space, which would feature a grand staircase connecting the three floors (see Figure 1) large solid wood floor joists were extracted and later became the stair treads for the grand staircase (see Figure 2). The existing wood floor and wood panelling was extracted, stripped, and milled down to become a texturally engaging statement wall which features REI members in action (see Figures 3 and 4). The use of reclaimed wood in this key customer journey point emphasises the strategic use of the reclaimed material to connect the customer with the product, which tells the story of the retail experience and the mission of the company. Additional reclaimed material from the TerraMai product line was used as flooring to seamlessly bring together the warmth and natural essence of the space and work cohesively with the other reclaimed material palette (see Figures 5 and 6).

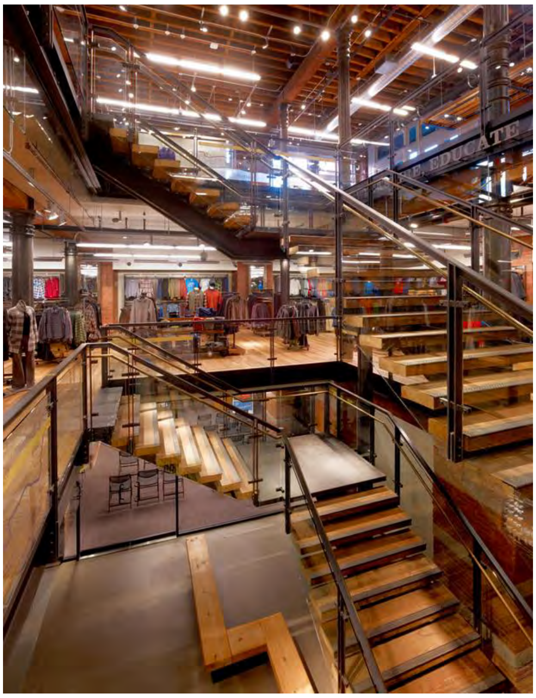

Figure 1. REI SoHo - New York City : Atrium staircase. Source: © TerraMai.

Figure 2. REI SoHo - New York City : Stair tread detail. Source: © TerraMai.

Figure 4. REI SoHo - New York City : Members feature wall. Source: © TerraMai.

Figure 3. REI SoHo - New York City : Building salvaged material. Source: © TerraMai.

Figure 5. REI SoHo - New York City : Completed store floor. Source: © TerraMai.

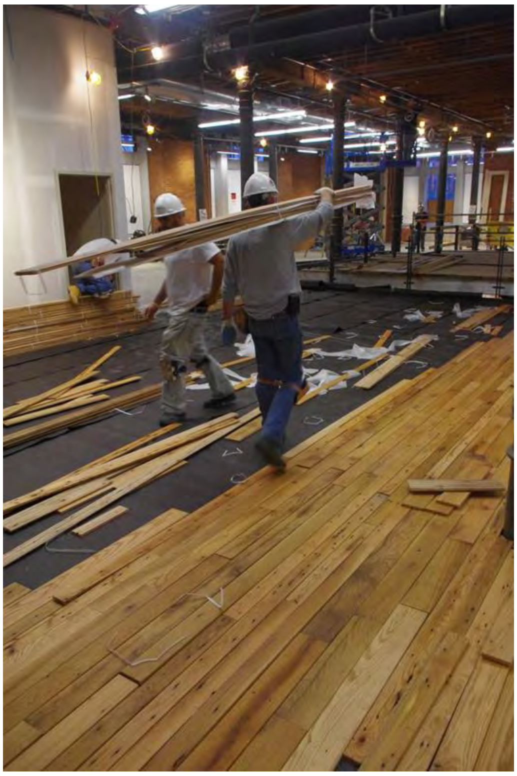

Figure 6. REI SoHo - New York City : Reclaimed wood floor installation. Source: © TerraMai.

AT&T Chicago: Technology meets Nature

Upon entering the new 10,000-square-foot AT&T store located in the heart of Chicago's famed Magnificent Mile, the customer is immediately welcomed into a world where technology meets nature. The use of reclaimed wood in the store is immersive, wrapping the entire store in a rich warm teak panelling. The reclaimed wood becomes a contrasting backdrop to the clean white and blue glow of the display fixtures, graphic elements, and most importantly the products and the brand logo (see Figures 7 and 8). With a brand mission to make people's lives better through technology, the reclaimed wood connects the customer to a material that is comfortable and familiar, warm and welcoming. As Design Principal Alex Shapleigh from Callison states "We wanted to focus on experiences in a way that humanizes technology, in a way that is fun, interactive and approachable."

Figure 7. AT&T Chicago Illinois store : Reclaimed teak paneling brand wall. © TerraMai

Figure 8. AT&T Chicago Illinois store: Reclaimed teak paneling local wall. Source: © TerraMai.

Starbucks: Creating a Neighbourhood Connection

At its core, Starbucks outlines it's mission as creating a culture of warmth and belonging, where everyone is welcome, connecting with transparency, dignity and respect. Reclaimed wood as part of the retail store experience takes the customers on a physical journey through the brand mission. As part of the exterior cladding and integrated into the branded signage (see Figure 9 and 10) starts the customers on a journey where reclaimed wood becomes a repetitious material product throughout the entire experience. The warmth of the material permeates the space and speaks to the honest nature of material and company, connecting the customer emotionally to Starbucks beliefs on sustainability and humanity. As reclaimed wood is often regionally sourced, coming from local barns or demolition sites, each store uses various reclaimed wood material products that give the customer the feeling that the store is rooted in the local community.

Figure 9. University Village, Washington – Reclaimed wood. Source: © TerraMai

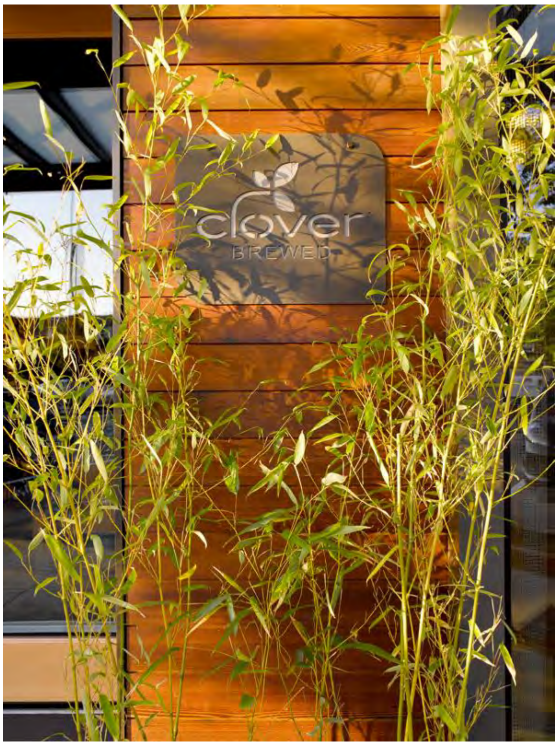

Figure 10. University Village, Washington – Reclaimed wood. Source: © TerraMai.

Lululemon: Local Customization Crafts Individual Identity

The use of reclaimed wood throughout the Lululemon Athletica stores reinforces their brand identity as a progressive, design-centric, environmentally friendly company. With a strong exterior presence, each store is given a unique identity through varying applications of reclaimed wood. Designing and crafting an individual identity for each store location allows the store to connect to the individuality of the brands consumers. It speaks of the company's individually unique brand ambassadors represented in each store location and connects its customers to a local community of athletic enthusiasts. (see Figure 11 and 12).

Figure 11. Lululemon store front Dallas, Texas – World Mix weathered siding. Source: © TerraMai.

Figure 12. Lululemon store front Lynnwood, Washington – World Mix mulit-colored tinted siding. Source: © TerraMai.

Next steps

To begin this multi-phase research and case study development, I will be conducting qualitative research through a series of consumer insights studies over the course of the next year. Through insights driven interviews, field studies and surveys, I will do a deep dive investigation into how consumers react to the use of reclaimed wood products within the retail environment in these four specific brands and store environments. This research is imperative to gain an in-depth understanding of how and why customers are responding to the use of reclaimed wood as a finish material product. The questions I intend to answer are:

- Do consumers feel more or less connected to the brand because of the use of reclaimed wood as an interior finish material product?
- Do consumers identify the retail brand based on the use of reclaimed wood as part of the store environment?
- What story does the reclaimed wood tell the consumer about the brand?
- Does the use of reclaimed wood create brand loyalty with the customer and as such create returned visits to the store?
- If reclaimed wood as a material product was not used within the store, would the consumer feel as strongly connected to the brand?

In addition to consumer interviews, I will also be conducting field studies and interviews with the store design teams and retailers themselves. Through these investigations, I hope to gain a working knowledge of how reclaimed wood products have been designed to become part of the store environments "kit of parts". Through this understanding, I hope to identify the opportunities where the use of reclaimed wood products in retail store environments is successful.

I am suggesting that if the use of reclaimed wood as a brand element is successful in creating a truly emotional response and creates a connection between the brand and the consumer, the brand will maintain the material within the store environment, resulting in extending the product lifecycle. Thus advocating, that within the context of the retail store, the reclaimed wood becomes a permanent brand element and that other less impactful brand elements may be switched out. If this can be achieved, using reclaimed wood as a permanent brand element will allow a retail store to reduce the frequency of total store remodelling and as such reduce construction waste.

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Obsolete peripherals: the ghost of the machine?

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Keywords: peripherals; obsolescence; e-waste.

Abstract: It is a commonplace that many products we buy bring along with them a range of both material and immaterial 'add-ons', some of which are obligatory, some necessary, some welcome and others unwanted. They are often unexpected, as many of these additional elements do not feature in advertising for products, in their retail display, or on packaging. Such 'add-ons' extend the notion of a product into an extensive series of material, economic, social and often quasi-legal relations. This paper considers these 'peripherals', especially as they relate to computer based consumer products, in relation to excess, obsolescence, and waste.

Introduction

The term 'peripheral' is strongly identified with 'add-on' devices that support computers. One definition offers

> *"…electronic equipment connected by a cable to the Central Processing Unit (CPU) of a computer"* (WordBook, 2014).

This starting point is both useful and limited. For example, power cords, charging docks and cradles, are not defined as peripherals, as they are not connected to the CPU. However, it is surely worth considering their status and contribution to both waste streams and domestic clutter? Conversely, increasing numbers of peripherals connect to a CPU without cables; technologies including Infrared, Wi-Fi and Bluetooth provide the connection. There are other anomalies and I offer these elaborations and observations.

The expanding realm of 'computer' peripherals

Peripherals used to be mainly devices for getting data out of computers—for storing, printing, and sharing. Increasingly, peripherals are also used for getting data in—from CDs and DVDs, the Internet, SD cards. External disc drives, card readers, docking mechanisms for music players, connectors for digital cameras, etc., have increased the number and range of such peripherals.

More peripherals in routine use are 'wireless': no physical cable connects directly to the computer, rather, Wi-Fi, Infrared, and Bluetooth, 'stream' data between devices. However, these peripheral devices are still connected to, and dependent upon, the computer's CPU. Moreover, many of these peripherals connect by cables elsewhere—to wireless routers and Internet modems. They may also connect, wirelessly or otherwise, to other computer-like products that contain computer processors, for example, gaming platforms. Additionally, many peripherals now themselves contain powerful computer processors, such that functions multiply (the printer, copier, scanner) and such that some 'independence', from the central CPU, is evident. However, there has also been an increase in highly dependent peripherals. For example, a DVD/CD drive, whether externally powered, or powered by the computer, has no function when not connected. It becomes an inert object.

A computer connected by cables to functionally dependent devices no longer captures the concept of peripherals. Instead, there is a complex arrangement of physically and wirelessly connected devices, characterised by both functional support and independence. Peripherals have their own peripherals and it becomes increasingly difficult to isolate and clearly define the 'leading' products from peripheral additions.

For example, the laptop, on which I am writing this, has eight ports and, at any one time, could connect as follows:

1. One USB port to a USB stick, either to back up files or to copy them to the computer
2. One USB port to an inkjet printer
3. The Ethernet port to my work telephone system
4. One Thunderbolt port to my mobile phone for charging
5. The second Thunderbolt port to a portable DVD drive as my computer does not have one built in
6. The 3.5 stereo jack port to a pair of headphones
7. The HDMI port, via a cable, to computer monitor so that I can 'mirror' my work on a larger screen
8. The SD card slot to a SD card containing digital photographs ready for importing.

However, there are more connections: my laptop is also connected via Wi-Fi to an extensive network of peripheral devices displaced in space; my workplace shared drives for file storage, the internet and email services; to the *Dropbox* servers through which I 'sync' my work across devices; to the *iCloud* servers through which *Apple* deliver much of their proprietary content; and to the *Backblaze* servers which back up my data.

Many of these additional elements—USB sticks, SD cards, headphones, etc.—are advertised as 'accessories' rather than peripherals. This implies that their consumption is voluntary rather than necessary. This might be strictly the case, however, these products are not marginal gewgaws, rather, they are increasingly necessary and integral—at least to the meaningful experience that the 'core' product is promoted as generating.

Given such complexity, there cannot be an overarching 'theory' of peripherals: there is too much variation between them, and too little in the way of an unambiguous definition. However, we might arrive at a rounded perspective and, through considering one common peripheral, the inkjet printer, we can see how peripherals relate to discussions concerning product durability, obsolescence and waste.[1]

Peripheral commodities

Given their subservient role, it is easy to forget that peripherals spring from the same consumer culture as the products they serve: they are all conceived, designed, developed, manufactured, and are themselves commodities with all the attendant concerns of resource depletion, manufacturing methods, sustainability, and matters relating to packaging, distribution, transport, retail display, marketing, etc. Indeed, there are three 'stages' that deserve attention; first, the conception, design, manufacturing, and retailing of peripherals; second, peripherals in use, including energy consumption, efficiency, pollution, elaboration of functions, and durability; third, what happens to peripherals when they are no longer in use, including obsolescence, methods of disposition, and waste: just as with any commodity.

However, peripheral devices exhibit some differences from many of the mainstream consumer products they support: they tend towards being generic, such that one printer will work with most makes of computer, and operating systems; technological innovations tend to lag behind those of the products they support, their turnover is often less rapid—in terms of both their product cycles and the acquisition-disposal cycles of individuals and institutions (Gabrys, 2011, Grossman, 2014).

Peripherals and obsolescence

Peripherals are subject to the same processes of obsolescence as the products they serve, and there have been several attempts to classify and describe these various types of obsolescence, including the planning of obsolescence as a means to drive repeat consumption and replacement (Burns, 2010; Maycroft, 2009a; Packard, 1963). Peripherals exhibit 'economic' obsolescence (Burns, 2010): many electronic goods, and their peripherals, are simply too expensive to repair, upgrade or

[1] Inkjet printers, and their own dependent additions, particularly printer cartridges, have also featured as one of only a small number of public scandals concerning forced consumption and waste, such has been the obviousness of attempts to use them to engineer consumption (Collinson, 2014; Robinson, 2013).

reuse. The falling use and price of inkjet printers, for example, has made repair far more expensive than replacement. Moreover, peripherals are increasingly marketed as not just being 'disposable' but as disposable and this applies to increasingly complex products. Inkjet cartridges, for example, many of which contain a microchip, are promoted as disposable, and upwards of two billion have so far been dumped in landfills, at a rate of 50 million a year in the UK alone (Collinson, 2014). This further drives the view of the parent printers as disposable: so successful have been industry efforts to build various kinds of obsolescence into inkjet cartridges that it often cheaper to buy a new printer than to replace cartridges (Robinson, 2013).

Stylistic obsolescence also marks peripheral design and promotion. Printers, routers, Wi-Fi stations, disc drives, USB sticks, and so on, all undergo regular aesthetic redesign, often alongside technical changes, but often without: for example *Apple* redesigned the shape of the connectors on their VGA cables from a rounded shape to a square one, as part of the redesign of other computer products and operating systems. Of course, that *Apple* offers its own cables and connectors in white not only make a strong branding statement, it invites consumers to consider the aesthetic coherence of their computers and peripherals. This example also shows how 'deep' into the chain of peripheral and add-on products fashion now extends[2]. Our featured inkjet cartridges, however, provide little scope for fashion-driven obsolescence; hence the efforts of manufacturers to make them drivers of repeat consumption in other ways.

Technological obsolescence dominates the marketing of electronic goods and their peripherals, and we can see both 'natural' technological obsolescence (the consequence of technological innovation) and 'planned' obsolescence which is designed to encourage, foster, and engineer repeat and replacement consumption. So, while many inkjet printer cartridges have been made smaller over the past decade, the corresponding amounts of ink supplied have decreased at a greater rate: some contain only a quarter, or even an eighth, the amount as their previous versions[3]. This pushes consumers towards both repeat purchases and increased disposal. Other technological 'innovations' also help engineer more consumption of cartridges, often as means to recoup revenue lost through falling printer sales (which continue to fall despite tumbling prices). These 'fixes' include bundling colour ink cartridges so that, when one colour runs out, all cartridges need replacing; the use of encryption technology (using yet more computer chips) such that non-branded cartridges will not work; elaborate designs which make the refilling of cartridges very messy at best and impossible at worst. Many cartridges are also incompatible across both brands and ranges within brands, despite them often being made by the same parent company. These 'innovations' have taken place against a background marked by the functional development of the printer—into scanner, film scanner, photocopier, and even fax[4]. Such elaboration, while offering many advantages to consumers, increases the number of associated peripherals and consumables—paper feeds and trays, film negative holders, etc.

Peripherals and e-waste

Peripheral products, components, cables, and connectors contribute significantly to various waste streams. Many small components—cables, chargers, plugs, storage media—tend to be disposed of in domestic waste streams (even though the disposal of some may be prohibited), often after a period of domestic 'storage' which lags behind disposal of the product they supported (Cwerner & Metcalfe, 2003; Maycroft, 2009b). Larger peripherals, especially in the context of the huge numbers associated with much institutional consumption,

[2] There is a further aspect of stylistic obsolescence that marks electronic goods and their peripherals significantly: their promotion and reception as objects that do not exhibit the marks of wear and tear favourably. There is no valued patina that belongs to electronic products (Burns, 2010).

[3] This is because the size of the sponges and ink tanks inside, which hold the ink, have been progressively reduced over the years—at a greater rate than the overall size reduction of the cartridge. This leaves a significant amount of empty space.

[4] The fax machine, and its associated paraphernalia, provides a good example of 'social' obsolescence that occurs when society as a whole moves away from a particular habit or behaviour, leaving a tide of associated material detritus (Burns, 2010).

may be disposed of through more formal, regulated processes.[5] Even here, however, they tend not to have featured strongly in recent research, for example in relation to the problems associated with the disposal of bulky items (Defra, 2011). Moreover, their 'value' for recyclers is low as they do not contain the valuable circuit boards and precious metals found in computers. In the US, for example, only five of twenty-three states include printers in mandatory recycling programs (Grossman, 2014).

The problems of pollution, dangers to health, global dumping, and so on all apply to peripherals as to their parent products. These have been well documented (Maxwell & Miller, 2012). Peripherals present some additional challenges; some being too small to effectively disassemble are just dumped, others are dumped because they lack valuable materials (Preton Ltd, 2010). Many peripherals have also escaped the scrutiny associated with the production of regulatory frameworks. Yet, the volume of such peripherals that has been disposed of, or is due to enter waste streams, is enormous (US EPA, 2009). Huge quantities of materials are spread across an immeasurable number of discrete but 'valueless' objects: unlike computers themselves, for example, in which discrete and valuable materials are contained within measurable and distinct units.

Conclusions

While compatibility with host devices has improved, we continue to consume ever more peripherals due to the need to 'service' more products and new categories of products. New categories of electronic goods, with their attendant peripherals, are intensively developed and heavily promoted. Currently, various Global Positioning System (GPS) devices and 'smart' watches are prominent. These represent increasingly energy intensive manufacture of ever smaller devices, the scale and specificity of which, let alone that of their peripherals, often rules out design for disassembly, repurposing, effective recycling, 'upcycling', and the like.

Cooper argues,

> *"there is a distinct lack of firm evidence that product improvement alone will be sufficient to steer the economy onto an environmentally sustainable course"* (2013, p. 143).

Indeed, we have no real criteria for guiding the designing of 'improvement' into such products and their peripherals. Nonetheless, design approaches promoting repair, reuse, recycling, compatibility, and standards would help alleviate many of the problems discussed above. A conscious move from Life Cycle Analysis to Life Cycle Design, with its focus on the materials of design, is advocated as an approach that can accommodate these principles (Vezzoli, 2014).

Solutions aimed at unused and waste peripherals might include 'take back' programmes: here, stronger regulatory control and coverage might provide the framework, for example, by expanding producer responsibility legislation to cover peripheral.[6] More protective consumer legislation might also be provided via warranties and guarantees (see Moles, 1985, for the most 'comprehensive' treatment) Apart from professional recycling, some small peripherals might lend themselves to vernacular reuse or recycling (Bramston & Maycroft, 2014). We might also envisage more novel approaches, product 'amnesties' or appeals, for example.[7]

There is, however, a large amount of e-waste, including peripherals and components that end up in landfill. Even those who live by scavenging on the world's dumps have no interest in recovering all waste materials. For example, when reclaiming copper from cables, usually by open burning, whatever is on the end of the cable (connectors, 'mice', plugs) is simply cut off and dumped. These bits and pieces, to quote Gabrys, "…accumulate into a sort of sedimentary record" (2011, p. vi). Esoteric solutions include dump mining, and bacterial

[5] Institutional disposal accounts for around 75% of all electronic waste sent for recycling and refurbishment (Grossman, 2014).

[6] The extension of legislation would, however, have to rest on a definition of peripheral; drawing attention to this lack of certitude might in itself be a useful exercise.

[7] As a child, I well remember the annual appeals launched by the BBC children's television programme 'Blue Peter'. These appeals, for small, unwanted items, for example unused keys, buckle, and in recent years mobile phones and CDs/DVDs, would be used to fund charity projects.

breakdown, but, as yet, this sediment of electronic and plastic defies our ability to reclaim it (or to stop it becoming such sediment). This left over peripheral matter; in the ground, in storage, and in domestic clutter, we might regard as 'the ghost **of** the machine'.

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Crafting sustainable repairs: practice-based approaches to extending the life of clothes

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Keywords: mending, repair, craft, design, clothes.

Abstract: Mass-produced 'fast fashion' has changed our relationship with clothing – cheap and easy to acquire, we are unlikely to take time to undertake simple repairs or address issues of maintenance, often caused or exacerbated by poor construction and low quality materials (see for example Goworek et al., 2012; You Gov, 2012; Fletcher, 2008; Birtwistle & Moore, 2007). Through complete lifecycle assessment, extending the useful life of clothes has been identified as the most significant intervention in reducing the impact of the clothing industry (Wrap, 2012). However, academic research emerging from both the UK and Scandinavia has identified practical, social, socioeconomic, systemic and psychological barriers that prevent consumers from performing even the most basic of repairs, and as a result damaged or worn items are discarded or taken out of active use (see for example Armstrong et al., 2014; Middleton, 2014; Cooper et al., 2014; Fletcher, 2013; Goworek et al., 2012; Laitala & Boks, 2012).

This paper explores the barriers to mending, different perspectives on the reasons behind them, suggested solutions and contemporary approaches to overcoming them. As textile designers and academics whose work is embedded in sustainable principles, we discuss the findings of our own practice-based approaches in relation to these, in order to consider the role fashion and textile designers can play in enabling solutions.

Research has been gathered through participatory design workshops and public engagement events, informed by review of historical, existing and emerging repair practices, and personal craft-led design praxis. We have explored ways to address the barriers, add value to the acts of repair by re-framing them as social design-led sharing activities, and discuss the potential of participatory craft praxis as a tool to motivate greater public engagement in repair practice.

Introduction

Mass-produced 'fast fashion' has changed our relationship with clothing; cheap and easy to acquire, consumers view fashion as 'throwaway' and are unlikely to undertake simple repairs or address issues of maintenance, often caused or exacerbated by poor construction and low quality materials (see for example Goworek et al., 2012; You Gov, 2012; Fletcher, 2008; Birtwistle & Moore, 2007). Through complete lifecycle assessment, extending the useful life of clothes has been identified as the most significant intervention in reducing the overall impact of the clothing industry and reducing the estimated 350,000 tonnes of clothing that goes into landfill annually (WRAP, 2012). However, academic research emerging from both the UK and Scandinavia has identified practical, social, systemic and psychological barriers that prevent consumers from performing even the most basic of repairs, and as a result damaged or worn items are discarded (see for example Armstrong et al., 2014; Middleton, 2014; Cooper et al., 2014; Fletcher, 2013; Goworek et al., 2012; Laitala & Boks, 2012).

In 2014 the authors worked for Zero Waste Scotland and WRAP on a series of collaborative repair and upcycling events for the consumer facing 'Love Your Clothes' (LYC) campaign. The approach taken aimed to engage audiences in conversation on the care and repair of garments, encourage active participation in craft based repair skills and showcase inspiring examples. The research and practice-based preparation for these events, as well as the resulting discussions, revealed some surprising and seemingly contradictory reasons about why people don't repair clothes.

This paper will first explore barriers to mending clothes, different perspectives on the reasons behind them, and suggested solutions to overcoming them. These will focus on roles that fashion and textile designers can play in enabling solutions and point to examples of repair practices led by contemporary designers, artists and activists such as Tom of Holland, Celia Pym and Amy Twigger Holroyd to illustrate these. Our own practice-based repair activities will then be introduced, followed by discussion of the findings: what they confirm and contradict, further insights that have been revealed, and the role fashion and textile designers. The potential of participatory craft praxis as a tool to motivate greater public engagement will be discussed, alongside associations between mending, craft and wellbeing.

Barriers to repair

Most commonly cited reasons for not repairing clothes are the financial cost involved, lack of time and skills. However, mending the results of wear and tear using stitch-based techniques - darning, sewing on buttons, and stitching hems, for example - require limited, low cost equipment, basic skill levels and little time (Middleton, 2014), with a multitude of tutorials easily accessible online (see for example "Mend a Hole", 2010; Comfort, 2014). UK research found that the majority of consumers disposed of damaged items (You Gov, 2012; WRAP, 2012b), so there must be other contributing factors beyond these initial barriers.

Traditionally, imperfect textile surfaces are strongly associated with poverty and wearing visibly worn or damaged clothes play a significant role in the characterisation of economic hardship (Kelley, 2009). The physical act of repairing clothes, particularly darning, also suffers from traditionally negative associations of 'women's work', times of hardship and wartime necessity, childhood chores, and isolated domestic drudgery (see for example Williams, 2004; image of 'The Influence of Women' in Long, 2011; Quinton, 2008; and paintings by Snyder, 1885; Renoir, 1908; and de Lelie, 1817 pictured in figure 1). These social associations still exist; academic research into clothing use behaviours found participants "avoid clothes with visible repairs in order to protect themselves and their families from stigma" (Fisher *et al.,* 2008: 31), for example.

Figure 1. Woman Darning Socks (de Lelie, 1817).

Contemporary consumer culture affords us the convenience of being able to avoid this stigma by no longer *needing* to repair clothes. The UK 'fast fashion' sector, characterised by cheap prices and low quality garments, has increased dramatically in the past decade (Defra, 2008), providing a vast array of readily available replacements and resulting in clothing being considered 'throwaway' (Birtwistle & Moore, 2007). Jonathan Chapman (2005, p.90-92) argues that this contemporary consumer culture has led to a sense of detachment from generic products that offer little emotional connection, which, in addition to low cost, could explain why they aren't considered worthy of repair.

This endless stream of cheap consumer products also has a disabling effect; as we no longer need the skills to make or reuse clothes we have become incapable of doing so (Farrer & Fraser, 2011). Kate Fletcher (2008, p.187) believes the nature of mass-produced garments contributes to this psychologically, because “the products themselves are presented to us as complete or ‘closed’, with an almost untouchable or sacrosanct status. This dissuades us from personalising them in order to make them our own”. So in addition to losing repair skills, psychological barriers may also prevent us from attempting to interact with them.

With consideration of these practical, social, socioeconomic, systemic and psychological barriers, the next section will introduce theory and practice-based solutions that have potential to overcome them, with a focus on those that could, and in some cases are, being led by fashion and textile practitioners.

Overcoming repair barriers

Mending artist and researcher Jonnet Middleton raises the significant point that traditional socioeconomic perceptions of repair are entirely outdated, “because, frankly, in this age of overconsumption, no one needs to mend anything anymore” (Middleton, 2014). Describing mending enthusiasts who disregard the stigmas and wear visibly repaired clothes with pride, Middleton suggests the potential to reframe repairs as a badge of honour: effectively subverting the social meaning of visibly repaired clothing. Designing to create new meaning is a strategy proposed by design theorist Jonathan Chapman (2005, p.109) in order to foster better emotional connections with consumer products, providing ‘conversation pieces’ that can facilitate servicing and repair (2005, p.18). The ‘Visible Mending Programme’ led by craft practitioner Tom of Holland takes this approach; his skilled visible repairs, masterclass workshops and commission services aim to “reinforce the relationship between wearer and garment… and hopefully persuade them that shop-bought clothes deserve care and attention too” (van Deijnen, *n.d.*).

The stereotypical image of isolated domestic drudgery is also being challenged by the distinctly cooler associations developing through the emergence of subversive practitioner led activities such as this; the co-curated ‘Department of Repair’ (Harvey et al., 2015), Middleton’s ‘Sock Exchange’ darning event (Middleton, 2010), and fashion design researcher Otto Von Busch’s (2011) Community Repair project are other examples that reposition of repair as an enjoyable social affair at practitioner facilitated events. Adopting the spirit of what is termed the Sharing Economy, this offers a “collaborative form of fixing [that] encourages the replacement of shopping (as a stimulus seeking activity), with more creative and social experiences, centered on the shared act of making and mending” (Chapman, 2013). They demonstrate repair and collaboration as strategic tools that designers can use to both mend damaged clothes and weave new threads of life into the social fabric, benefitting the collective wellbeing of communities by bringing people together through shared experiences (Von Busch, 2011).

Amy Twigger Holroyd (2013) is a design researcher who has been exploring the craft-wellbeing relationship in the context of sustainable fashion: how craft can contribute to both personal wellbeing while also challenging the ‘hegemony of contemporary mass-produced fashion culture”. Her research is centred on re-knitting rather than repair as such, but addresses the same psychological barrier created by the ‘closed’ nature of clothes, as introduced earlier (Fletcher, 2008, p.187), in order to extend the life of clothes. To do this she takes on a ‘meta-design’ role that moves away from traditional model of ‘designer as author / maker’ to a supportive role of ‘designer as collaborator’, by opening up her design skills and knowledge to help skilled amateur knitters personalise items of ready-made clothing. In doing so, greater emotional connections with mass-produced clothes are fostered, engendering the sense of individuality, self-definition and affirmation of identity within users (Chapman, 2005, p.109). Further to this, the craft skills also provide personal rewards: a sense of achievement and space for meditative reflection.

The next section will outline our practice-based repair activities that adopt elements of these solutions: facilitated visible, participatory, and social repair, in particular Twigger Holroyd’s concept of ‘meta-designer’, that opens up design skills and knowledge to support others.

Activities

The authors facilitated a series of Love Your Clothes (LYC) public engagement events in 2014 at the Highland Wool Festival and in John Lewis stores across Scotland, with the aim of exploring practice based design approaches to support greater public engagement and participation in garment repair, in order to extend the active life of clothes. In addition to the review of barriers and suggested solutions outlined previously, the preparation for these events included informal conversations with skilled local amateur craft practitioners to learn about their experiences of and perspectives on craft repair skills; these revealed insights that will be discussed in the findings section.

Personal craft praxis was also employed in the preparation to inform the practical requirements of acting as a 'meta-designer', following Twigger Holroyd's (2013) methodology of independent design research to develop techniques through iterative cycles of planning, sampling and reflection to develop ideas, write instructions and designing resources (see Twigger Holroyd, 2013, for an in depth description). For our events, these were darning and simple embroidery stitch techniques that could be used for creating personal, visible repairs. These had to be adaptable, to suit different personal styles, but unlike Twigger Holroyd, who undertook purposive sampling with skilled amateur knitters, the audience at the open public events had unknown skill levels, so it was necessary to develop techniques that would be accessible to complete beginners.

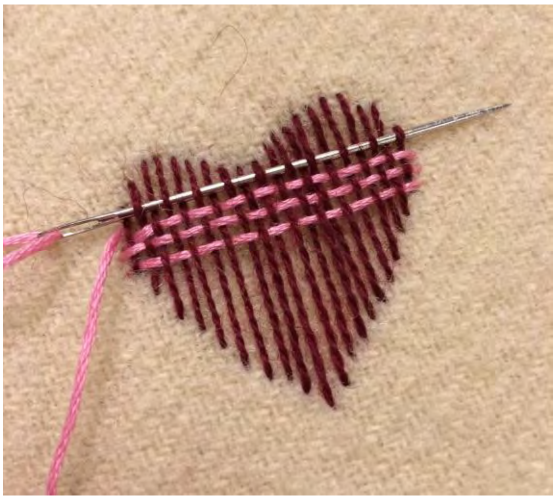

Figure 2. Darned heart motif developed for the LYC events (image credit: Angharad McLaren).

Further to these practical considerations, the techniques were selected for their potential to be decorative, inspiring and expressive. A darned heart-shaped motif (figure 2) was developed, for example, to tie in with the LYC message by inviting people to 'wear their heart on their sleeve', showing their love for their clothes. Or, in other words, a metaphor that offered an easily cognisable meaning to provide the foundation for emotional connection (Chapman, 2005, p.109). Expressive embroidery stitches were also employed to enable personalisation (figure 3).

Figure 3. Expressive, decorative embroidery stitches (image credit: Shirley McLauchlan).

To reframe repair as social design-led sharing activities, the events took a participatory approach, offering demonstrations and advice on darning and embroidery techniques, while also encouraging conversations around mending and the value of our clothes. Participants were asked to share their own hints and tips to help others extend the life of clothes; these were displayed prominently on tags at the events and shared to a wider audience using online social media platforms (figures 4 and 5). This attempted to increase the visibility of mending practices, as well as encouraging active participation in the Sharing Economy ethos through altruistic means.

The qualitative data generated by these activities is clearly limited, personal, and specific. As such it is not generalisable to the wider population, but has offered further insights into the barriers to repair and solutions to overcome them. It also provided a platform to explore a design-led role, which is discussed in the following section.

Figure 4. Shared repair hints and tips at Highland Wool Festival (image credit: Angharad McLaren).

Figure 5. Tweet of shared repair hints and tips at John Lewis Glasgow event with Shirley McLauchlan.

Findings and discussion

Conversations around clothes repair during the LYC events, revealed that cost, and lack of time and skills were indeed commonly cited barriers to repair. However, surprises were found in conversations with local amateur craft groups who are extremely skilled at embroidery techniques and will typically spend a great deal of time and resources on embroidery as a pastime, but do not tend to apply this skill to repairing and mending their clothes. Damaged clothes were sometimes 'upcycled' into new products – bags, patchworks or artworks – using their creative capacities, or used as rags around the house and garden. Many ended up being thrown out, not considered useful or good enough to donate or pass on.

Volunteer textile repairers at a stately home who evidently have skills, time and patience to undertake advanced embroidery repair techniques were also disinclined to mend or personalise their own clothes. All participated in many other pro-environmental practices, such as composting, sharing car journeys and recycling. Mostly older generation women, they had all learnt the specific skills required for mending, such as darning, at a young age, and associated it with isolated domestic chores and times of economic hardship. This is consistent with the traditional perceptions of repair and poverty, and Twigger Holroyd's (2013) findings that skilled amateur knitters, despite having the skills to make complex garments from scratch, did not personalise or repair ready-made items due to their seemingly 'closed' nature.

The engagement with other pro-environmental practices also suggests a lack of knowledge about the environmental impact of the fashion industry and clothing waste, and, interestingly, most people at the events were motivated more by the thought of saving loved garments than environmental reasons. The events also revealed that garments that were repaired were often 'favourites', which confirms that an emotional connection can overcome the psychological barriers proposed by Fletcher (2008), or that the damage somehow 'opens' a garment, offering a way past it's initial 'closed' or 'sacrosanct' nature.

Traditional repair techniques such as darning were perceived as not only time consuming and laborious processes, but also scruffy and messy looking in practice, not appropriate for the workplace for example. As a result, any damage in a visible place renders garments un-mendable. The decorative but contemporary style aesthetic offered in our examples was enthusiastically received as an alternative, challenging preconceived notions of traditional repairs. Some chose to follow our instructions step-by-step, while others were confident adapting the designs to suit their own style; either way connects with the clothes at a material level, adding a personal touch that could help to engender the sense of individuality, self-definition and affirmation of identity within users (Chapman, 2005, p.109).

The active participation confirmed the potential of Twigger Holroyd's 'meta-design' role in supporting participants to personalise garments through repair, and in particular highlighted the importance of personal design-led craft-praxis in the preparation stages of this to ensure the techniques developed were accessible, adaptable, inspiring and expressive. Not all participants found the techniques easy to master, however, especially those with little or no craft skill experience, and this led to them feeling frustrated or disappointed with the results. Further refinement of the techniques and supporting instructive materials could be trailled to develop them for wider accessibility.

Whatever their personal experience of the techniques, in opening up conversations around repair practices, we found many were keen to share their own hints and tips to help and motivate others. This social, altruistic enthusiasm supports the ethos of the Sharing Economy (Chapman, 2013), and suggests that more could be done to facilitate skills sharing between those with more advanced skills and experience, such as the skilled textile repairers whose already volunteer their skills for altruistic purposes. This could be built upon by incorporating further altruistic measures; Celia Pym has taught darning techniques on old hospital sheets that were returned afterwards for re-use (Alter, 2008), for example, hence over coming practical barriers with skills training while also offering civic engagement and wellbeing benefits of 'doing good' in society (Robotham et al., 2012).

Lastly, a lack of knowledge about the environmental impact of the fashion industry and clothing waste was revealed in our research. The LYC events revealed the potential for participatory craft praxis as a tool to motivate greater public engagement with sustainability. They offered a space to discuss and reflect upon these topics in a social, informal and creative setting, provided 'conversation pieces' to facilitate servicing and repair (Chapman, 2005, p.18), and also help make repairs, the act of repairs, and the stories behind them, more visible.

Conclusions

Repairing damaged and worn clothes is one way to reduce the impact of the fashion and textiles industry, by reducing the amount of waste and extending the life of clothes. Financial costs, and lack of time and skills are the most commonly cited barriers to repair but this paper explored further social, socioeconomic, systemic, and psychological barriers that explain why damaged clothing is not repaired.

Exploring the complexities behind these initial barriers and solutions to overcome them revealed valuable insights to inform our own sustainably motivated practice. Repair practitioners are taking different approaches to encourage and motivate repairs, with a common thread of participatory activities that reframe mending as a social, enjoyable affair that embody an altruistic Sharing Economy ethos. Increasing the visibility of repairs, while also reframing their meaning, challenges the traditional, outdated views of mended clothes as signifiers of poor socioeconomic status. Designing visible repair patterns that are contemporary, stylish, accessible and can be personalised offers potential for wider uptake of repair practices, making them personal, meaningful and socially suitable to be worn in the workplace for example.

Amy Twigger Holroyd's (2013) 'meta-designer' methodology redefines the designer's role as a supportive collaborator in personalising garments in these social, participatory settings, rather than being solely the author / maker of original works. This approach was successfully adapted to support personalising repairs in the LYC public engagement events. Further work could develop these to better support complete beginners, and be adapted to include further repair techniques such as Swiss darning, patchwork or applique.

Future research aims to continue investigating attitudes towards decorative repairs, developing new work that incorporates mending skills as decorative elements and exploring their use as inspirational and educational tools for different audiences through participatory events.

Acknowledgments

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Clothing longevity perspectives: exploring consumer expectations, consumption and use

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Keywords: clothing longevity, consumer behaviour, sustainable fashion, life cycle

Abstract: The production, distribution, use and end-of-life phases of the clothing lifecycle all have significant environmental impacts, but complete lifecycle assessment has identified that extending the active life of garments through design, use and re-use is the single most effective intervention in reducing the overall impact of the clothing industry (WRAP, 2011). In response, Government funded clothing longevity research seeks to develop and test industry-led design strategies to influence and enable consumers to keep garments in active use for longer (Cooper *et al.*, 2014). While recent UK research has indicated significant potential to influence more sustainable consumer behaviour (Langley *et al.*, 2013; YouGov, 2012), up-to-date qualitative research is required to discover how consumer attitudes, expectations and behaviours in relation to clothing lifetimes affects garment care and clothing use. This will help to inform industry-led strategies by understanding where effective changes can be made that will potentially have most impact.

This paper presents preliminary findings from a Defra funded action based research project, ‘Strategies to improve design and testing for clothing longevity’. Qualitative research methods are used to explore consumer attitudes, expectations and behaviours at purchase, use and disposal stages of garment lifetimes, and gather data on practices of garment wash, wear, care and maintenance in everyday life. The research findings are discussed in relation to industry-led strategies aimed at extending the life of clothes.

Introduction

The production, distribution, use and end-of-life phases of the clothing lifecycle all have significant environmental impacts but life cycle assessment has identified that extending the active life of garments through design, use and re-use is the single most effective intervention in reducing the overall impact of the clothing industry; in fact extending the average life of clothes by just three months of active use per item would lead to a 5-10% reduction in each of the carbon, water and waste footprints and save billions from the costs of resources in clothing supply, laundry and disposal in the UK (WRAP, 2011).

> *Quite simply, if clothes have a longer usable life, they can be replaced less frequently – reducing the volume discarded and meaning fewer resources are consumed in manufacturing.* (Cooper *et al.* 2013: 3).

The current Defra funded project, ‘Strategies to improve design and testing for clothing longevity’, aims to explore the technical, behavioural and strategic obstacles to implementing innovative and sustainable product development processes that could extend clothing lifetimes. It will seek to identify the knowledge, skills, processes and infrastructure that could support wider adoption of design for longevity in the clothing industry and make garments last longer, including industry’s role in supporting sustainable consumer behaviour.

The paper aims to explore consumers’ attitudes, expectations and behaviours, and influences on these, and will discuss initial findings in relation to suggested industry- led strategies aimed at enhancing clothing lifetimes. Beginning with a discussion of the impact of consumers on clothing lifetimes, initial findings of qualitative research with different consumer groups targeted as key markets for clothes with enhanced durability are discussed.

Clothing lifecycles: consumer impact on longevity

Purchase

In the design and production phases, industry can support the longevity of garments through measures such as designing classic styles, using more durable materials and stitch construction, or testing to ensure high standards of colour fastness (Cooper *et al.,* 2010). However, the rise of fast fashion in the UK, characterised by low cost, poor quality fibres and short garment lifetimes (Defra, 2008), has been attributed to a 'throwaway' attitude to clothing that is only expected to be worn a few times (Birtwhistle and Moore, 2007).

Encouragingly however, recent WRAP research has found that there are positive signs of consumer demand for longer lasting clothes. In a UK survey, 52% of respondents acknowledged they "could do more to buy items that are made to last for longer while continuing to look good and would like to do so"; pertinently for retailers, there is a willingness to pay higher prices for durability (Langley *et al*., 2013). Consumer interest may be limited, however, by the lack of recognised ways to measure and communicate longevity (WRAP, 2011), by feeling limited in their ability to check for and assess durability, and the extent to which they do this (Langley *et al.,* 2013).

Consumers' expectations of clothing durability vary depending on factors such as the context of use and retail price (Bide, 2012). However, studies that seek to quantify clothing lifetimes (e.g. Langley *et al.,* 2013) do little to explicate whether consumers consider these factors at point of purchase, or how they affect behaviour during the use phase, which the following section will discuss.

Use: Wear, Care, Maintenance & Repair

Clothing care (e.g. washing, bleaching, ironing, drying, and professional dry cleaning) and maintenance (e.g. removal of pilling) are processes that paradoxically enable the continued use of clothes and contribute to their inevitable deterioration (Kelley, 2009). How well consumers understand care labels, whether they follow them, and the frequency of washing, has a significant impact on how quickly this deterioration will occur. Contemporary clothes may be more likely to wash out rather than wear out due to incorrect selection of wash cycles, and use of increasingly abrasive detergents (ASBCI, 2013), excessive use of fabric conditioner (Chiwese & Cox Crews, 2000), unnecessarily frequent washing, and tumble drying (Laitala *et al.*, 2011). However, while most respondents claim that they already do everything they can to look after items so that their clothes are kept in regular use for longer, men, younger people and those on higher incomes were found to lack confidence in their clothing care ability (Langley *et al.*, 2013).

Many consumers would 'seriously consider' wearing more clothes a second time before washing (Langley *et al.*, 2013), but most studies into consumer clothing care focus on the environmental and financial benefits of reduced energy, water and chemical usage (e.g. Bain *et al.,* 2009; Dombek-Keith & Loker, 2011) and relatively little is known about consumers' actual care and maintenance behaviours, or knowledge and understanding of the impact of care processes on clothing lifetimes.

Studies of the socio-technical systems of laundering suggest that understanding the interrelated social and technical dimensions of clothing wear and care patterns, such as personal standards of cleanliness, style, social norms and judgments on appearance, as well as the physical 'systems of provisions' can identify opportunities for influencing change towards more sustainable practices (Shove, 2003). Others suggest that understanding consumers' social and experiential relationship with clothing during the use phase, as well as their capacity for adequate care, maintenance and repair, is crucial to ensuring garments are kept in continued active use (e.g. Fletcher, 2012; Laitala & Boks, 2012; Niinimaki & Armstrong, 2013). Studies such as these have highlighted that how much garments are valued determines the level of care and maintenance they will receive and the likelihood of repair, and different types of value have been identified beyond purchase price, such as functional, aesthetic, emotional, social, and sensory value (see for example: Fletcher, 2012; Laitala & Boks, 2012; Niinimaki & Armstrong, 2013; Pink, 2005) that could potentially be fostered through industry led strategies such as using naturally anti-bacterial fibres to keep clothes smelling fresher for longer (Laitala & Boks, 2012). What determines the end of a garment's life and associated implications for re-use and disposal will be discussed in the next section.

Re-use & disposal

Determining garment disposal is largely subjective and variable, as “two people may have very different criteria to judge the point at which deterioration represents the end of an item’s useful life” (Bide, 2012:126). Some have been found not to mind pilling or small holes, for example, whereas others would discard these as too worn out (Laitala & Boks, 2012). Psychological reasons such as a desire for something new, boredom or because garments are out-dated are also common reasons for disposal (see for example Cooper *et al.*, 2013; Laitala & Boks, 2012; YouGov 2012). As a result, many garments are discarded before the end of their potential lifetime (Black, 2008).

A large amount of used clothing that is still wearable is donated to charities in the UK for re-use (WRAP, 2012; Fisher *et al.*, 2008; Birtwhistle & Moore, 2007), but supply is larger than demand in the UK and a large amount is exported overseas where it has been reported to have negative effects on local economies (Rodgers, 2015). As such, increased re-use within the UK is a preferred route to clothing longevity (WRAP, 2012). However, social stigmas and hygiene concerns limit purchase of second-hand clothing (Fisher *et al.*, 2008). Other re-use methods, such as selling through online platforms (e.g. eBay), passing on to friends and family, or swapping at ‘swishing’ events rely largely on garments maintaining their value (Birtwhistle & Moore, 2007; Laitala & Boks, 2012).

For garments that are no longer wearable, the method of disposal is pertinent as those sent for recycling can be used again as industrial rags, or shredded down to use for insulation and carpet underlay (WRAP, 2012). Generally, disposal is based on convenience, and consumer awareness of what can be recycled, how, and the benefits of doing so, has been found to be limited; many garments end up in the bin (Fisher *et al.*, 2008; Birtwhistle & Moore, 2007). Ensuring the value of old textiles is understood and providing services to enable greater recycling can therefore ensure material re-use in alternative contexts.

Research design

This research aims to explore consumer perspectives on clothing longevity in order to consider where industry and policy could influence change. Three key consumer groups, identified in previous research (Langley *et al.*, 2013), were targeted as priorities for longevity research: younger consumers most associated with ‘fast fashion’ consumption (F); older, professional ‘slow fashion’ consumers with a tendency to focus on durability and high quality (S); and parents of school age children whose clothes are subject to high wear and tear (P). These groups were chosen as they represent distinct market segments with different shopping habits, demands of clothing, and lifestyles that influence expectations, attitudes and behaviours relating to clothing lifetimes; these variables were explored using the following qualitative methods.

Focus groups

Four focus groups were held in November and December 2014 with a total of 29 participants, lasting approximately two hours each. Purposive sampling recruited participants in the three consumer segments outlined above and a higher proportion of female participants were selected to reflect the fact that women purchase more clothes than men. Mintel (2014) estimate that 49% of consumers’ clothing spending is on women’s outerwear, as opposed to 26% being spent on men’s outerwear. Additionally, women are often responsible for buying clothing for children and male relatives and are therefore the dominant purchasers.

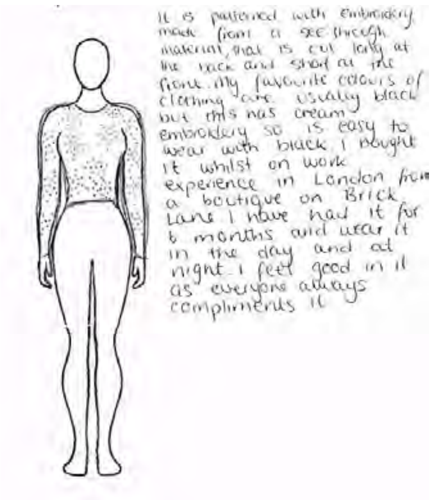

Figure 1. Focus group favourite garment exercises

As an icebreaker, each focus group started with an exercise asking participants to sketch and describe a favourite garment (Figure 1). This was designed to set the scene around relationships with clothing and explore different types of value associated with clothing. Participants were invited to discuss their everyday relationship with clothing, framed around the four key stages of garment lifecycles: purchase, use – including wear, care, maintenance and repair – re-use and disposal.

Figure 2. Images of common garment failures used as focus group discussion points

Participants were next asked to consider how long they expect different garment types to last and why, to discuss experiences of common garment failures shown in a series of images (Figure 2) and explore what determines the end of a garment's life, and open up discussions around care, repair and maintenance behaviours. Participants were asked to describe specific examples of short-lived garments, as well as those that had lasted a long time, to explore the reasons why.

Further exercises asked participants to reflect on what would make their [or their children's] clothes last longer and to give their thoughts on current and proposed clothing longevity strategies and influences, such as a durability index suggested by WRAP (2012) or product durability guarantees such as those offered by Flint and Tinder's ten year hoodie (n.d.). Focus group transcriptions were analysed with NVivo software, coding emerging themes and concepts.

As qualitative research the findings cannot be used to generalise about the UK population as a whole, but the rich textual data offers insight into existing expectations, attitudes and behaviours related to clothing about which relatively little is known. As the research is currently work-in-progress, only selected findings are discussed in the following section.

Selected findings and discussion

Results revealed a variety of factors that affect clothing longevity during the different stages in the garment life cycle, purchase, use and disposal. They suggest that changes in industry practice and public policy could potentially lead to longer clothing lifetimes at each of these stages.

Consumers want garments to last a reasonable lifetime in relation to their expectations, which are influenced by material and garment quality, how frequently it will require laundering, care processes, maintenance, style, fashion trends, brand, purchase price and considerations of the frequency and intensity of wear in its intended context of use (e.g. work or casual wear). Participants found it hard to quantify their expectations of the lifetime of particular garment types, though, and when they did there was considerable variation.

The fast fashion group appeared to most commonly experience garments not lasting as long as they had expected; there is a sense of futility and resignation, despite wanting them to, and investing time in maintaining them. The individuals expressed feeling trapped by the cheap, fast system of short-life garments, which 'obliges' them to frequently buy new. Overall, the slow fashion group were most likely to say that all their clothes had met their expectations of longevity and expressed confidence in assessing durability; however they had still experienced disappointingly short-lived garments.

In line with the findings of Langley *et al.* (2013), consumer demand for longer lasting clothes was evident, particularly among younger fast fashion consumers. The evident dissatisfaction, disappointment and frustration associated with short-lived clothing, along with the rise of campaigns such as Fashion Revolution Day (2014) increasing awareness of the impact of ethical standards and waste in the clothing industry, suggests that this demand may be set to increase.

Participants agreed that assessing the durability of a garment is challenging and that price did not necessarily positively correlate with high quality. For example, a respondent from the 'slow fashion' group said:

> *I think that's, it's sort of experience isn't it? …you can't always 100% tell, because you could buy something and be surprised by it, but you do tend to look at the quality overall, you know, you fold it up. You might look at the seams. You might… just look at the general hang of it, how the fabric reacts, what it's made from. So, those sorts of things. It's not necessarily indicated by the price I don't think*.

Participants found it particularly hard to assess if a garment would pill and some were unsure of causes, prevention or pill removal techniques. Consistent with findings of previous research (Langley *et al,* 2013; WRAP, 2011) consumers' capacity for making clothes last is therefore largely affected by the quality offered by retailers, as well as their own ability to assess durability and capacity for adequate care and maintenance. This could be supported by increasing durability standards and provision of a durability index that could help consumers assess how long a garment is likely to last; they could then make informed decisions based on the personal factors found to influence their purchase decisions, such as intended context of use. Communicating advice on prevention of pilling, as well as provision of removal advice and equipment could also help.

Across the focus groups, there was an implicit understanding that care processes impact upon garment lifetimes, but care labels are rarely followed beyond the first wash and many consumers find them hard to understand. In the most part, assessment of care is based on experience and knowledge of fabric/fibre types, revealing a kind of tacit materials-based competence. Not all know or understand the reasons for having separate detergents for different colours or fibres, and fabric conditioner overdosing is evident, which has been found to increase propensity to pilling (Chiwese & Cox Crews, 2000). Laundry practices are based on convenience and valid concerns about energy consumption (i.e. financial and/or environmental drivers). For example, families may have high volumes of washing and lack time to separate loads by fibre type, and individuals living alone have low volumes of washing but may not want to run many small loads.

Better information provision about clothing care could help facilitate longer lasting clothes as well as reduce the water, energy and chemical impacts of laundry processes. However, resources to this end exist, such as a comprehensive, user-friendly online guide that is signposted on garment care labels, launched in 2014 (Clevercare, n.d.). The effectiveness of this in engaging consumers is unknown, but across the focus groups younger fast fashion participants responded most positively to the suggestion of supportive online resources.

The value of an item was found to affect the use relationship: consumers appear more likely to hand-wash, separate colours, maintain and repair higher priced items. Value is understood beyond purchase price, though – emotional value, exchange potential, social value, aesthetic and sensory value are also important factors. To facilitate these types of value, industry could employ various targeted strategies: enhancing clothing's emotional durability and exchange potential by selecting materials that age gracefully (Chapman, 2005), or increasing sensory value by using fabrics that smell fresher for longer, such as naturally anti-bacterial wool fibres (Laitala & Boks, 2012).

Summary and next steps

This paper has introduced ways in which consumer attitudes, expectations and behaviours impact upon clothing lifetimes. Initial findings from qualitative research, currently work-in-progress, that explored these aspects in key consumer groups are consistent with previous research that revealed a demand for longer lasting, more durable clothes (Langley *et al*., 2013).

Within the group segments explored, distinct priorities and attitudes to clothing longevity were discovered that reveal areas where clothing brands at different market levels can focus strategies to support clothing longevity.

The full findings of this research will be published in a technical report for Defra at the conclusion of the project in September 2015.

Acknowledgments

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Towards BIM-integrated, resource-efficient building services

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Keywords: BIM; embodied carbon; resource efficiency; building services.

Abstract: Recent research has highlighted the importance of increasing the resource efficiency of building services. In this paper, a literature review of life cycle assessment and embodied carbon studies clearly signposts the need for more research on the embodied impacts of building services. Theoretical and practical challenges are identified in the use of LCA methods in construction along with possible solutions compatible with BIM-led design. A case study of horizontal, ducted fan coil units demonstrates that variations in embodied carbon of similar units could be associated with variations in total cooling capacity. This raises the possibility that metrics could subsequently be devised to predict embodied carbon for a generic class of fan coil units. When combined with data on operational carbon emissions and product service life this could enable optimisation of lifetime carbon impacts. Implications of these results are explored and recommendations made for future studies.

Introduction

If resource efficiency is defined as making 'best use of materials, water and energy over the lifecycle of built assets to minimise embodied and operational carbon' and other environmental impacts (WRAP, 2015), its implementation requires measurement and mitigation of these impacts. Building on previous research into resource efficiency of building services (CIBSE, 2014), this study considers how better calculation methods for the embodied impacts of these services might support building information modelling (BIM) tools to enable resource-efficient choices of services. Before this, we appraise current gaps in knowledge about the resource impacts of building services. A case study into embodied impacts of fan-coil units is then described and its implications discussed, after which recommendations are set out for future studies.

Literature review

Published research into resource efficiency in the built environment has prioritised operational energy efficiency, driven by greenhouse gas (GHG) emission targets and the building sector's responsibility for a third of global anthropogenic emissions (Ibn-Mohammed et al, 2012). The main theoretical approach used in these studies has been life cycle assessment (LCA), an approach supported by general and construction-specific ISO standards (BSI, 2006a, 2006b, 2011, 2013).

The importance of embodied impacts

Recent studies indicate that improved operational energy efficiency of buildings will raise the embodied proportion of lifetime building environmental impacts (RICS, 2010, HM Government, 2010). The term 'operational carbon' (OC) hereafter refers to CO_2 equivalent emissions from a building or its components during its use phase, while 'embodied carbon' (EC) describes non-operational emissions from all life-cycle phases. Estimates from published research of the EC proportion of lifetime building carbon emissions vary owing to their sensitivity to parameters such as building lifetime and the lack of agreed calculation methods (Ng, Chen & Wong, 2013). Consequently studies are needed that can measure embodied impacts as robustly as has been done with operational impacts. While recent LCA studies have considered whole buildings as well as specific building elements (Ortiz, Castells & Sonnemann, 2009), few have measured life cycle impacts of building services, especially their embodied impacts (Passer, Kreiner & Maydl, 2012).

LCA studies of building services

The few published LCA studies into building services produced since 2004 have yielded relevant insights: (a) When comparing systems or products, lower embodied impacts are often associated with higher operational impacts (Hekkila, 2004, Chen, Zhang & Setunge, 2012) or higher reusability of an alternative (Franklin Associates, 2008); (b) Embodied impacts of service components relative to mass can exceed those of building fabric (Chau et al, 2007); and (c) Obtaining reliable data on raw materials within composite building services components presents challenges (Chau et al, 2007, Whitehead et al 2012). These points support a need for accurate measurement of embodied impacts of building services.

Embodied carbon based studies

Following a UK government report that recommended 'whole life carbon appraisal' of construction products (HM Government, 2010), recent UK studies have measured the EC intensity of buildings and their components in CO_2 equivalent, using global warming potential (GWP) to represent multiple environmental impacts addressed by LCA, while meeting LCA standards (Moncaster & Symons, 2013). Results show that building services can represent 3-15% of *initial* EC of a typical office building, worth 20-126 kg CO_2e/m^2 (CIBSE, 2014), while *recurring* EC of building services from 30 years of maintenance and replacement may be six times the value of initial EC (Franklin & Andrews, 2010).

Theoretical challenges

In seeking reliable measurements for embodied impacts of building services, LCA is challenged theoretically by the uniqueness and complexity of buildings and resulting variation of method between LCA studies (Buyle et al, 2013, Cabeza et al, 2014). This can be redressed (a) by using LCA standards specific to buildings and building products (BSI, 2011,2013); (b) by considering only GWP (RICS, 2010), thus avoiding weighting between impacts; and (c) by studying comparable building components rather than hard-to-compare entire buildings. The latter approach underlies Type III Environmental Product Declarations (EPDs) (BSI, 2013, EPD International, 2015).

Practical challenges

LCA studies of building services are also challenged by practical gaps in data, tools and policy. Life cycle inventory (LCI) databases in construction typically contain simple materials and not composite building services components (Hammond & Jones, 2011, Ecoinvent, 2015). EPDs can fill this data gap, but are limited by being voluntary and costly, while UK building regulations omit embodied emissions. The data gap might be resolved by developing parametric methods to predict embodied life cycle impacts of generic building services components (Moncaster & Symons, 2013).

LCA tools and BIM integration

Three types of tools can measure life cycle impacts of building components (Cabeza et al, 2013). These are (a) product comparison tools such as Simapro (2015) and GaBi (2015), (b) whole-building decision tools such as Athena Eco-calculator (2015); and (c) whole-building assessment frameworks such as BREEAM (BRE Global, 2014) and LEED (USGBC, 2009). The first two measure impacts quantitatively, while the third combines quantitative and qualitative methods. Product comparison tools are complex and ill-suited to lay users, while other tools sometimes include embodied impacts of building services (EtoolLCD, 2015) but still face data gaps.

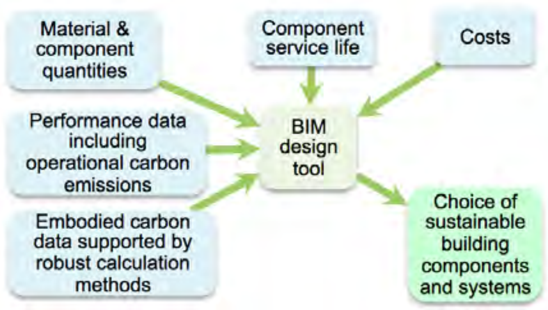

Figure 1. Integration of carbon, quantity, service life and cost using BIM.

A BIM approach to design may improve whole building support tools either by interfacing a 3D model with an LCI database (Capper et al, 2014, Tah et al, 2012) or by adding 'EC' fields to BIM files representing building components, as in CIBSE's 'product data templates' (CIBSE, 2015). Figure 1 illustrates how this promises integrated calculation of carbon and 4D-design data for rapid decision-making. However, for this to happen the theory, metrics and data informing EC values must be robust.

Case study into fan coil units

Given the need for suitable metrics and data on embodied impacts of building services, the hypothesis to be tested is whether a parametric approach can reliably predict the EC value of composite building services components. This requires measurement of the EC value of a 'base component' representing a component class. This value is then multiplied by one or more coefficients such as mass or power rating to predict the EC value of components of different sizes. For empirical investigation, the UK office sector was chosen, due to its high value within mechanical and electrical building services work (BSRIA, 2014) and commercial property stock (BCO, 2013). The most common item of installed central air-conditioning plant in the UK is the fan coil unit (FCU) (BSRIA, 2014), for which selection is typically based on operational performance and cost (CIBSE, 2008a, ACR News, 2009).

The study focuses on water-side FCUs, (see Figure 2) in which heating or cooling is modulated by the flow rate of hot or chilled water, and which make up 75% of the UK market (CIBSE, 2008a). The main components and materials within horizontal, ducted, water-side FCUs, are (a) galvanised steel casing lined with polyurethane acoustic foam, (b) fans and motors made mainly of steel, aluminium and copper and (c) aluminium and copper heating and cooling coils. Details of the full range of FCUs produced by a UK based manufacturer were obtained, including masses of main materials, yield loss in manufacturing and cradle-to-gate transport data. This was combined with reference data on the carbon intensity of materials (Hammond & Jones, 2011) and energy used in manufacturing and transportation (DEFRA/DECC, 2015) in order to calculate carbon coefficients and EC values. Product details were obtained from four other UK manufacturers of comparable FCUs that had been tested against similar standard operating conditions. A comparison was made of the ratio between relative mass and total cooling capacity of each FCU by size and by manufacturer. Assuming consistency of raw materials between manufacturers, the EC intensity of FCUs in relation to total cooling capacity was compared by manufacturer. Explanations for variations between manufacturers were considered and a sensitivity check done to explore uncertainty in the results. Results were then considered vis-a-vis the relationship between operational and embodied carbon.

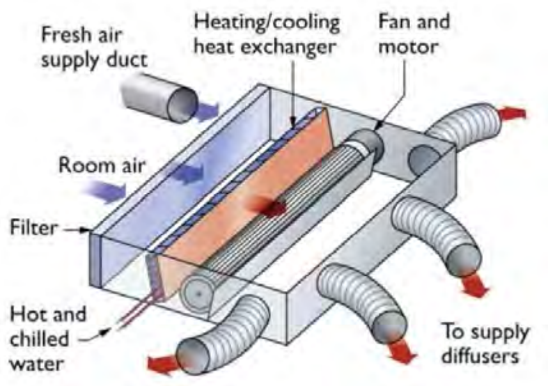

Figure 2. Basic configuration of a horizontal fan coil unit (BSRIA, 2013).

Results

Table 1 shows a bill of materials averaged from a range of FCUs of between 2-8 kW in total cooling capacity. Comparing columns 3 and 4, steel represents over 77% of FCU mass but only 56.2% of total EC of the product, as the greater carbon intensities of other materials give them larger shares of total EC. The total EC of the FCU is 193 kg CO_2 e for a total mass of 69 kg, giving an EC coefficient of 2.8 kg CO_2 e/kg. The total value of EC also exceeds the EC of raw materials within the finished product, as 24.3% of total EC is from scrap steel and polyurethane foam generated in making the FCU's casing.

How do parameter values vary at different levels of total cooling capacity (TCC)? While the material breakdown of each FCU is broadly consistent across the size range, total mass and EC both rise proportionately with TCC as shown in Figure 3.

Material type	Average material mass (kg)	Average EC of material ($kgCO_2e$ /kg)	Average material mass (%)	Average EC of material (%)
Steel	53.1	105.4	77.2	56.2
Aluminium	5.5	43.7	7.7	21.5
Copper	5.3	15.3	7.5	7.7
Zinc	0.7	3.0	1.0	1.6
Poly-urethane foam	4.4	25.7	6.5	13.0
Total	69.1	193.1	100	100

Table 1. Fan coil unit average material and embodied carbon (EC) content.

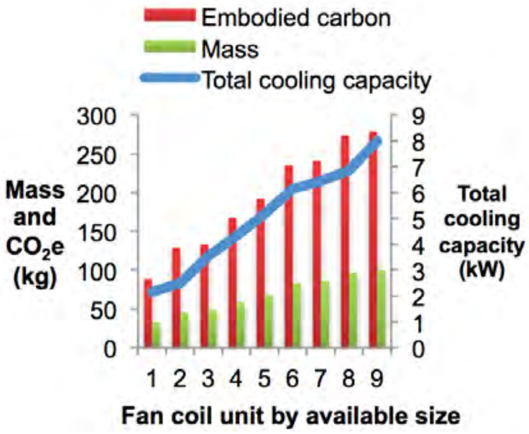

Figure 3. Fan coil unit range by mass, embodied carbon and total cooling capacity.

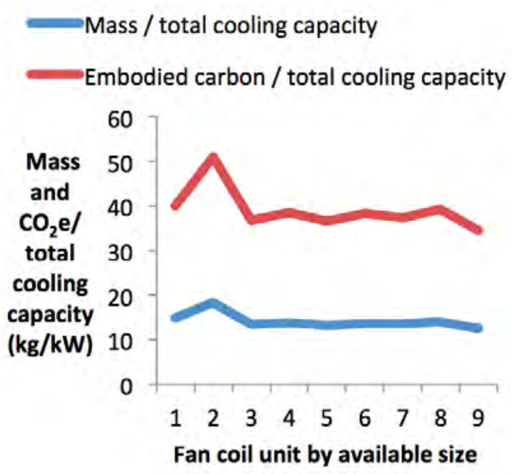

Figure 4. Fan coil unit mass and embodied carbon relative to total cooling capacity.

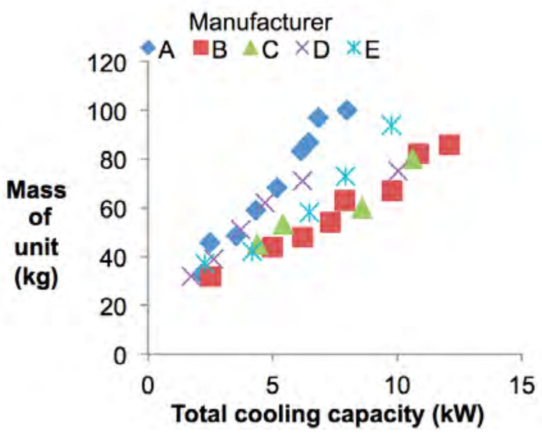

Figure 5. Fan coil unit total mass by total cooling capacity and manufacturer.

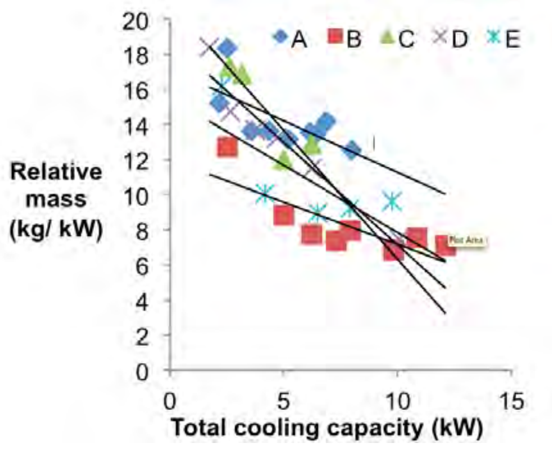

Figure 6. Fan coil unit relative mass vs. total cooling capacity, by manufacturer.

Figure 4 shows that mass and EC of each FCU relative to TCC varies slightly downwards as FCU size and TCC increase, except for a spike at the second model in the range. The spike is explained by an increase in FCU mass between points 1 and 2 on the X-axis that exceeds the increase in TCC over this range. Generally, as FCU size increases, mass and EC rise absolutely but fall relatively in relation to TCC. This suggests that TCC could act as a coefficient to transform the EC values of a base FCU into values for an FCU of any particular size, provided that anomalies in FCU mass can be explained.

Figure 5 plots mass against TCC of FCUs made by five UK manufacturers, demonstrating that TCC varies directly with mass for all manufacturers, with the rate of variation differing between manufacturers.

Figure 6 plots the relative mass against TCC for the five manufacturers, showing an inverse relationship. Downward pointing trend lines for each series of coordinates indicate that larger models are evidently more efficient on a power to weight basis. However, this trend varies in strength between manufacturers with an r^2 value of between 0.47 and 0.93.

Based on the detailed analysis of FCUs of one manufacturer, we assume that all five manufacturers use consistent proportions of materials across their size range, and that these are associated with consistent proportions of EC. If the variations between manufacturers in mass and mass/power ratios at each level of TCC in Figures 5 and 6 can then be explained, a base FCU could subsequently be defined, from which EC values of other units might be predicted by varying selected parameters.

Possible explanations for variations in mass and mass/power ratios between manufacturers might include (a) the use of materials of different densities to make similar parts; (b) differences in dimensions of the FCU casing, likely to affect relative mass of the FCU; and (c) differences in design quality giving rise to differences in material density. With limited data available drawn from product literature, these issues may only be explored tentatively via an exploratory sensitivity check.

Sensitivity check

To consider the first explanation, if galvanised steel casing represents the majority of FCU mass and UK-produced galvanised steel is of standard density, varying steel thickness should significantly vary FCU mass. Manufacturers A and C are known to use 1.2mm gauge steel and manufacturer E uses 1mm gauge steel, with typical densities of 9.083 kg/m^2 and 7.888 kg/m^2 respectively (Custompartnet, 2015). If the FCU casing represents 70% of average FCU mass, as is the case in our empirical case study, then manufacturer E's models should have 1-(0.7-(7.888/9.083*0.7)) = 9.08% less mass than those of manufacturer A. In Figure 6, the effect of reducing the mass of FCU 'A' by 9.08% would shift its mass / power curve closer towards the curve of FCU 'E'. This would explain approximately 30% of the difference in mass between manufacturers A and E at each level of TCC. While this cannot explain the mass discrepancy between manufacturers A and C, who both use 1.2mm gauge steel, it shows the importance of material density in explaining variations in mass.

Discussion

The case study shows that variation in EC of FCUs of similar type at different rated levels of total cooling capacity are in theory predictable as long as differences between FCUs by manufacturer can be explained. The aim would be to compare FCUs of similar function but varying embodied content, and eventually compare alternative types of cooling systems, given sufficient data.

But what do these results mean in relation to the balance of embodied versus operational impacts?

The answer requires several calculations. The difference in initial EC between FCUs made by different manufacturers in this case study could be estimated by assuming that EC content per raw material was consistent between manufacturers, while material quantities may vary between manufacturers. Values for operational energy consumption and carbon emissions could also be estimated for each FCU given assumptions about daily and seasonal loads. However, to balance the EC and OC of a particular FCU would need two additional calculations.

Firstly, lifetime OC emissions of a building or building component vary with length of its service life and future changes in carbon intensity of electricity grids. A typical service life for an FCU based on its economic and technical lifespan is 15 years (CIBSE, 2008b), but new commercial leases last on average 5 years (BCO, 2013), at which point tenant fit-outs may involve scrapping FCUs. The calculation of FCU operational emissions must therefore be based on robust assumptions. Secondly, the recurring EC associated with maintenance, replacement and disposal of an FCU must be calculated and added to values of initial EC within the present case study. These calculations must precede estimation of lifetime carbon as each can increase the EC/OC ratio for an FCU. Product service life and embodied and operational carbon intensity are all therefore variables that influence the lifetime resource efficiency of a choice of building service product.

Conclusions and recommendations

This study has highlighted the need for more research on the embodied impacts of building services. It shows that BIM design tools can include assessment of these impacts if suitable metrics and data are first developed. A case study of horizontal, ducted coil fan coil units showed that variations in embodied carbon of similar units could be associated with variations in total cooling capacity. This clearly indicates that if differences between FCUs by manufacturer could be explained, metrics could be devised to predict the embodied carbon of a generic class of FCUs. Calculation of lifetime carbon impacts of FCUs was observed to depend on additional calculations, assumptions and variables including product service life.

In order to test fully the method of embodied carbon analysis used in this study, the preliminary findings would need to be validated using additional data. This should cover material composition and initial and recurring embodied carbon content of FCUs produced by a representative sample of manufacturers. The results should then be subjected to a detailed sensitivity analysis. In principle, if such a method can robustly predict embodied carbon impacts of a class of component, other environmental impacts linked to material composition might be predicted. More widely it is recommended that further studies are carried out on the embodied impacts of building components in order to raise awareness on the need for the design and application of robust methods to balance embodied and operational impacts of buildings.

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Life cycle assessment and the eco-innovation generation

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Keywords: Life Cycle Assessment; eco-innovation; ecological crisis; decoupling; product lifetime.

Abstract: The ecological crisis is directly related to climate change, depletion of natural resources, high generation of waste and so on. A review in industrial practices is a necessary condition to confront this crisis. New proposals to achieve sustainable development have emerged, among them is the life cycle assessment (LCA) methodology. This tool has been increasingly accepted as a way to assess the environmental impacts associated with all stages of a product's life, encompassing the entire production chain: the extraction of natural resources, transport, production process, consumption and disposal of products (waste). This methodology has the potential to reduce ecological problems, minimizing the environmental impact of the productive activity. The LCA studies approach and measure each phase of a production chain, providing opportunities to identify critical points for environmental innovations, also known as eco-innovations. The decoupling, that proposes a reduction of material consumption in the production of the same amount of goods and services is discussed in this paper, alongside with the use of LCA and eco-innovation. The conclusion is that these three axes of the literature have to be more integrated, considering the huge potential to provide news means to tackle the ecological crisis. To summarize: (i) decoupling is a new production paradigm derived from the ecological crisis, intending to produce more with less environmental recourses; (ii) the LCA allows critical points in the production process to be found; (iii) eco-innovation enables the type of changes to be developed that replace the old one at the critical points. The co-evolution of these literatures promises many fruitful results that are still at their beginning, one possibility is to design a longer lifetime product.

Introduction

The global discussion on environmental sustainability and most recently the green economy, has gained central and undeniable force in recent years. The industrial capitalism, based on the continuous and cumulative development of new products and services, has generated different environmental impacts. As a direct result, the planet's capacity to provide resources and absorb the waste produced by civilization is moving quickly to a critical and irreversible point.

According to the study conducted by International Resource Panel (IRP), the consumption of natural resources has accelerated and grown dramatically, bringing as a direct consequence, the reduction and even the depletion of many of the planet's natural resources (UNEP, 2010). It is estimated that US$3 trillion per year would be needed in new investments in resource supply to meet demand, if no other action was taken (McKinsey Global Institute, 2011). Thus, one of the greatest challenges of our time is to adjust production and consumption practices to accommodate the planets' limits.

One of the proposals arising from this challenge is decoupling that focuses on improving resource productivity, as a means to disconnect the increase of production from natural resources. In economic terms, it means that negative environmental impacts decrease, while value is added to production (UNEP, 2011; UNEP, 2014).

According to UNEP (2010), from a life cycle perspective, all production ultimately serves the purpose of consumption. Thus, in the final consumption perspective, all emissions and the resource used during production process are assigned to the final consumption of the products and services. This life cycle perspective is sustained by a specific methodology, the LCA. LCA as a new support methodology for both production and consumption provides the necessary information for greater eco-efficiency through the production processes. It also collaborates with product design, resulting in a lower impact on the environment, and through considering the whole life cycle involved from the extraction of raw materials to final disposal of the product (waste).

Specifically, considering the use of natural resources, the consumption intensity of resources, will directly depend on the methods used to produce the goods and services and also on the product project. With particular reference to the question of product design, the article will approach the proposals for extending the product's lifetime.

This article can be categorized as a bibliographic and exploratory study and its goal is to present the importance and use of the proposed decoupling, LCA and eco-innovation when designing a product with an extended product lifetime.

Ecological crisis and the decoupling proposal

The current capitalist model based on continued growth of production and consumption, is directly impacting the planet's capability to provide resources and absorb waste from these activities.

The production and consumption have mutual causality link and according to Lipovestky (2010), this relationship promotes an ever-growing path in economic activity. The larger volumes produced and consumed have caused serious social and environmental consequences and are at the origins of a so-called ecological crisis.

Decoupling, is a valuable concept that means a reduction in the rate of use of primary resources per unit of economic activity. This dematerialization is based on less use of material resources, energy, water and land, generating the same amount of economic output.
According to the report by UNEP (2011) the consumption of natural resources - defined in the report by natural assets deliberately extracted from nature by human activity for its usefulness in creating economic value - have grown critically. This expansion has generated concerning environmental impacts. The consequences go beyond the declining of these natural resources, it also includes the way in which they are extracted (pollution and water misuse), the production processes used (emission, pollution), the consumption (emission and pollution) and post-consumption (waste e pollution), i.e., the resource entire life cycle.

The growing concern about the environmental issue within the production segment, suggests a new production model, which asks for greater eco-efficiency through production processes, resulting in a lower impact on the environment. This leads to the idea of a growth disconnected from larger environmental impacts, i.e., a more sustainable economy. To achieve this, it is necessary to have an absolute reduction in the use of natural resources on a global level.

One of the better ways to achieve decoupling is by using a methodology that has been widely accepted, due to its range of analysis, clarity and reliability of the data, the LCA. According to UNEP (2014), LCA is widely adopted in order to assess environmental impacts, associated with all the stages of a product's life. The use of this methodology aims to avoid impacts and inefficiencies throughout the entire life cycle. LCA provides a large viewpoint on environmental concerns by compiling an inventory of relevant energy and material inputs and environmental releases. In this way, the LCA helps to evaluate "the potential impacts associated with inputs, releases and interpreting the results, in order to help a more well informed decision" (UNEP, 2011).

Life cycle assessment and the eco-innovation

In the recent past, proposals related to environmental improvements were focused on the inner perimeter of the companies. But according to initiatives based on the life cycle, this focus was extended to all stages, from cradle-to-grave. It goes

> *"from raw material extraction through to materials processing, manufacture, distribution, use, repair and maintenance, and disposal or recycling" (UNEP, 2011),*

from cradle to grave. Each step is analysed and quantified in order to check the local, regional or global impact that the process will have on the environment.

In these terms, LCA is a key methodology to orientate innovation to a more sustainable economy which requires an absolute reduction in the use of natural resources on a global level. The LCA analyses how products may affect the environment during their resource consumption, manufacturing processes, use, and also discarding. It is a holistic approach, which provide an examination of consecutive and inter-linked stages of a product system (Pujari, 2004).

The productive process studied usually involves the following stages: design; acquisition / extraction of raw materials, manufacturing, use / reuse / maintenance, recycling and waste disposal. Each of these steps are analysed and quantified in order to check the local, regional or overall impact, this process, product or service will have on the environment.

One of the great advantages of the LCA approach is that when contemplating the entire product life cycle, it can check if there is the transfer of the environmental impact of a cycle stage to another or from one category of impact to another. Thus avoiding that a measure taken in order to reduce the overall impact of the final product may end up transferring the impact to the other phase or other impact category or even worse promoting an higher overall impact. Therefore, it made it possible to recommend the redesign of a product, in order to ensure that it becomes less harmful to the environment. As a result these new products may possibly have a greater useful life, besides generating minor environmental impacts during use and since they have a broader lifetime, they would generate a lower natural resources use (due to a reduction in their purchasing frequency).

The LCA methodology has four specific phases to be followed:

1. Defining scope and objectives of the study;
2. Analysis of inventory;
3. Environmental Impact Assessment;
4. Interpretation of results.

The key phase is the interpretation, when is it possible to point out minor or greater changes on the technology used. Because the LCA focus is in the environment, these changes bring environmental benefits, and innovations that are called eco-innovations (as shown in Figure 1).

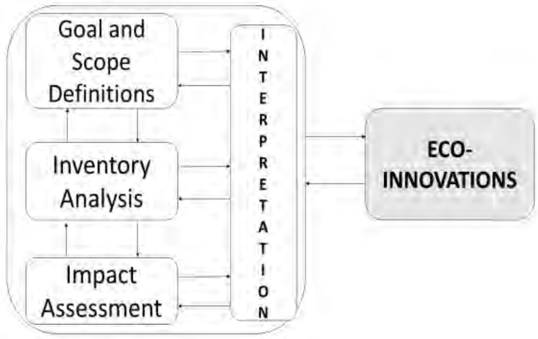

Figure 1. LCA enabling eco-innovations.

But what is eco-innovation? According to OECD (2009) reports, eco-innovation is an innovation that results in a reduction of environmental impact, no matter whether or not that effect is intended. Kemp et al (2007) defines eco-innovation as the production or harvesting of a product, production process, service or management method that is new business for the firm or the end user and which results, through its lifetime, in a reduction in the environmental risk, pollution and other negative impacts on the use of natural resources.

Eco-innovations may occur through different ways of combining materials and labour force, generating new products or entering a new attribute to an existing product, in a new production method, the discovery of new sources of raw materials, the change in composition of a product, etc. Smart companies are treating sustainability as a new frontier of innovation, in this case eco-innovation (NIDUMOLU et al, 2009).

O´Hare (2010), points out that the product life cycle is considered to be a crucial aspect for two main reasons. First of all, if only part of the life cycle is considered, more significant problems in other areas of the life cycle may be missed. Secondly, solutions that are effective for one life cycle phase may create new environmental impacts in other life cycle phase. Therefore, after running an LCA study and having all the information on the impacts generated by the product throughout its life cycle, the promotion of greater product longevity is made possible. This is an important area of eco-innovation which has many important barriers linked to industrial power and economics. Even if this issue goes beyond this paper objective, it is worthy to say that this tool has the potential to provide crucial data against planned obsolescence.

According to Cooper (2010), public discussion on product life spans has historically concentrated around the concept of planned obsolescence. The reasons for an opposite movement against the planned obsolescence and a search for an extension of product life expectancy are many, ranging from the excessive use of natural resources to unacceptable amounts of waste and emissions arising from these productions.

According to Pujari (2004), in recent years, there has been an upsurge in the reporting of research in the area of eco-innovation, or 'green' innovation, regarding R&D, production processes, new products and new services. Starting from information derived from LCA studies, the proposed eco-innovative product can bring benefits in terms of lower consumption of natural resources, especially when developing a product with longer lifetime. This is obtained by making it more durable, harder to break or making it easier to be repaired or be upgraded, giving it a new product life.

Product life extension is an increase in the utilization period of products, which results in a slowdown of the flow of materials through the economy. According to Stahel (1986), it refers to the economy in which we ''do not repair what is not broken, do not remanufacture something that can be repaired, do not recycle products that can be remanufactured''.

Discussion

Designing sustainably means getting the most use of the materials and energy that goes into a product. A great way to do this is by extending its useful life. This proposed extension of the useful product life is aided greatly by the LCA methodology, and its potential to promote eco-innovation.

The interpretation LCA phase is what most matters to this article, especially the improvement proposals of an LCA, because at this point, the opportunities to eco-innovations can be clearly observed.

Both proposals (LCA and eco-innovation) are adequate to promote an increase in the product's lifetime. It allows, therefore, the introduction of the advantages of a higher product lifetime to users and society in a clear and proven way. An important role of LCA is to compare accurately, the environmental benefits brought about by the increase in the useful lifetime of the product. This enables, for example, the comparison of the impact that would be generated by an early disposal of the product - as occurs in most of the projects, typically based on the programmed obsolescence practices - and the alternative impact if it is designed to be a more durable product. Another example is related to the LCA studies on the trade-off between longer lasting products and energy consumption, as in the case of a more durable product, the energy consumed during its production will be distributed over a longer useful lifetime, contrary to what occurs on the product traditionally produced today.

Besides, an eco-innovation derived from the LCA study, may be one of a longer product lifetime and cost-effective in the consumption of energy or water during its use. Additionally, this type of eco-innovation may provide a lower generation of waste during the production or use, the use of recycled raw materials, among other environment-friendly characteristics.

Environmental problems, are of course, not restricted to the productive sector, several other aspects are involved, as in the case of consumption. At least when it comes to product design and production, eco-innovation and LCA can be regarded as a form of optimizing these activities and thus reduces their environmental impacts.

Conclusions

This paper intended to present a preliminary discussion linking decoupling, life time assessment methodology and eco-innovations. We have described some initial findings from our ongoing research investigating these three axes of literature, having in mind the contribution, from an industrial production point of view, towards reducing the ecological crisis. According to the study, each proposal, LCA and eco-innovation can jointly collaborate with increased product lifetime and decoupling. The LCA studies have the means to identify critical points where eco-innovation is recommended. LCA studies can also help to evaluate the existing trade-offs between the design of an enduring or a short usage lifetime product. Because LCA is a methodology that encompasses all stages of the production lifecycle, including the product discharge, it has the potential to replace products designed to become obsolete far before their functional lifetimes have expired.

It is hoped that this work can motivate practical applications of the eco-innovations arising from the LCA methodology, leading to new product lifetime designs and that future case studies can further contribute to this understanding.

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Eco-innovation: its inverse relationship with natural resources use and waste generation

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Keywords: eco-innovation; ecological crisis; decoupling; natural resources; waste; product lifetime.

Abstract: Contemporary society still bases much of its economic development on the extraction and consumption of natural resources. Industrial production, which uses these resources, has caused negative impacts on the environment. Not only because of the increasing amount produced, but also due to the product designs and manufacturing processes that do not account for these impacts. Some alternative proposals have emerged to manage environmental problems in industry reflecting major awareness of the limitations of natural resources, as well as the negative effects of greenhouse gases emissions and environmental degradation. Both aspects are primarily driven by the development of industry and society's patterns of production and consumption. The growing concern regarding the ecological crisis has led to a new idea that a more sustainable economy requires an absolute reduction in the use of natural resources on a global scale. The decoupling formulation means a reduction in the rate of use of primary resources per unit of economic activity. This dematerialization is based on less use of material resources, energy, water and land, generating the same amount of economic output. New modes to confront environmental problems depend, at least in part, on environmental innovations. Also known as eco-innovations, this type of innovation can help to reduce the consumption of natural resources, greenhouse gases emissions and the generation of waste. This study proposes eco-innovation as a more efficient way of using less natural resources. The discussion takes into consideration the decoupling proposal.

Introduction

Generation of goods and services are highly dependent on the use of natural resources. Discards, greenhouses gases emissions and waste become typical elements of the production process. These negative aspects raised discussions on the hyper-consumption culture and its impacts on the environment. Recent studies show how these aspects consequently lead to serious results such as global warming, increasing depletion of natural resources, and excessive waste generation (Léna, 2013; Van Den Berg, 2011; UNEP, 2011, UNEP, 2012a; Stern, 2007; Reilly, 2012; Veiga and Issberner, 2012; Latouche, 2012). All these - among other severe consequences - have been deteriorating living conditions on the planet.

Until very recently, there was an implicit belief that the physical expansion of the economic system and the consequent degradation of the environment could be unlimited. This belief also included confidence in an economic system that would provide whatever was necessary for continuous growing production and consumption. In recent years, science has proved this was a misbelief. Several studies confirm the existence of an ecological crisis and the need for urgent solutions (Léna, 2013; Van Den Berg, 2011; UNEP, 2011, UNEP, 2012a; Stern, 2007; Reilly, 2012; Veiga and Issberner, 2012; Latouche, 2012).

Opposing the conception of an endless economic growth, the concept of decoupling has been developed to encompass the notions of environmental limits, the life cycle of natural resources and the impacts of the global economic growth on the economic production (UNEP, 2011). Decoupling refers to a disconnection between the growth of environmental impacts and resource consumption to address the ecological crisis (UNEP, 2011).

Some of these studies highlight the need for a deep change and the current predominant approach of incremental improvements which is not enough (Pujari, 2006; Lastres et al, 2005). Within this context, eco-innovations stand out in the debates as one possible way to help the reduction of the negative impacts of production and consumption on the environment.

Eco-innovations may occur through different ways of combining materials and production processes, creating new products or proposing a new attribute to an existing product in a new production method. They can also be related to the discovery of new sources of raw materials, opening new markets and market niches, changing the composition and extending the lifetime of a product, among others. This will ultimately reduce or minimize the environmental impacts of the production/consumption processes. A review of industrial practices becomes an important element to identify areas where eco-innovative efforts should focus.

This paper is organised as a literature review. It aims at discussing the definitions of eco-innovation and how it can help to reduce environmental problems. Eco-innovation and decoupling proposals play an important role in these discussions.

Ecological crisis and decoupling

According to the European Parliament (2009), since 1980, the global extraction of abiotic and biotic resources increased from 40 to 58 billion tonnes in 2005. Scenarios for 2020 predict a full resource extraction of about 80 billion tonnes as the volume required to sustain global economic growth. The World Bank report prepared in 2014 estimated that cities with 1.3 billion tonnes of Municipal Solid Waste (MSW) production in 2010 are expected to increase this production to 2.2 billion tonnes by 2025. These facts illustrated what scientific research has already pointed out about the origins of the current ecological crisis.

Over time, concern about environmental issues has led to the development of different concepts and terms such as sustainable development, green economy, industrial ecology and degrowth, among others, which reflect different economic, social, political and environmental interests. (Léna, 2013; Van Den Berg, 2011; UNEP, 2011; UNEP, 2012a; Stern, 2007; Reilly, 2012; Veiga & Issberner, 2012; Latouche, 2012).

Decoupling is embedded in almost all ideological or theoretical notions of the ecological defence battle. As reported by UNEP (2011), decoupling is based on the growing concern of society with environmental issues. It suggests a new model which seeks greater eco-efficiency through the production processes, resulting in a lower impact on the environment. This concern about sustainability and impacts generated by global economic growth introduces the idea of a growth disconnected from larger environmental impacts (UNEP, 2011). It means that a more sustainable economy requires an absolute reduction in the use of natural resources on a global level. In this sense, decoupling proposes a reduction in the rate of use of primary resources *per unit* of economic activity. It is a dematerialization based on less use of material resources, energy, water and land, generating the same amount of economic output.

According to UNEP (2011), these impacts may be caused by deliberate interventions into natural systems such as land cover change and resource extraction, or by unintended side effects of economic activities, such as emissions and waste. Thus, a focus on decoupling requires attention both to the amount of resource use linked with economic activity, and to the environmental impacts associated with this resource use at all stages of the life cycle.

The proposal is manifested in two ways. The first approach is the "resource decoupling". It allows an increase in the production of goods and services and/or quality of life with the relative decline of the exploitation of non-renewable natural resources, through the progressive reduction in the use of non-renewable physical resources per unit of output. The second is the "decoupling of the environmental impact”. It refers to negative externalities arising from the economic production and the subsequent environmental impact, which could be reduced with the development of innovations aimed at controlling the external impact and the replacement of inefficient production processes.

Definitions of eco-innovation

Recent literature on innovation introduced different concepts to describe a specific type of innovation, with potential to reduce the impacts on the environment. Some of these concepts refer to "green", "sustainable", "environmental" and "eco-innovation". These terms have been used almost interchangeably, but Schiederig et al. (2012) point out that, though these concepts seem to address the same content, they slightly differ in their descriptive precision. These authors also highlight six important aspects in the different concepts: innovation object; market orientation; phase; impulse; and level (Schiederig et al., 2012). The "phase" aspect refers to the fact that the full life cycle must be considered (for material flow reduction). This aspect is present in the eco-innovation definitions adopted in this paper, particularly in Kemp and Pearson's (2007) and Reid and Miedzinski (2008).

One of the first uses of the term in the specialized literature was by Fussler and James (1996). They define eco-innovations as "new products and processes which provide customer and business value but significantly decrease environmental impact". Some later definitions of eco-innovation added an approach from the industrial dynamics perspective. Andersen (2008) and Foxon and Andersen (2009), for example, define eco-innovation as an innovation that is able to attract green rents in the market, reducing the net environmental impacts, while creating value for organizations. The definition from the Organisation for Economic Co-operation and Development (OECD) underlines that the reduction of the environmental impacts does not need to be an intention of the eco-innovation. It is defined as "the creation or implementation of new, or significantly improved, products (goods and services), processes, marketing methods, organizational structures and institutional arrangements which – with or without intent – lead to environmental improvements compared to relevant alternatives" (OECD, 2009). Building on this definition, Arundel and Kemp (2009) emphasize that eco-innovations are not limited to environmental motivations as economic reasons can produce environmental benefits as the side effect of other goals. In their own words: "Eco-innovations can be motivated by economic or environmental considerations. The former includes objectives to reduce resource, pollution control, or waste management costs, or to sell into the world market for eco-products" (Arundel and Kemp, 2009). Taking into account both types of motivation, though, Ekins (2010) stresses that eco-innovation can be understood as a change that benefits the environment to some extent, but that can only be judged considering an increase on the economic and environmental performance.

Focusing on the product life cycle and in accordance with the purposes of this discussion, the present study adopts Kemp and Pearson's (2007) conceptualization for its theoretical grounding. Based on the definition of innovation from the Oslo Manual (2005)[1], Kemp and Pearson (2007) developed a definition for eco-innovation, proposed at a report for an EU funded research project called "Measuring Eco-Innovation" (MEI) [2]. They describe eco-innovation as "the production, assimilation or exploitation of a product, production process, service or management or business method that is new to the organization (developing or adopting it) and which results, throughout its life cycle, in reductions in environmental risks, pollution and other negative impacts of resources use (including energy use) compared to relevant alternatives" (Kemp and Pearson, 2007).

This definition adds environmental gains when compared to other technologies available for the same purpose (Kemp and Arundel, 1998; Rennings and Zwick, 2003; Kemp, 2009). However, Kemp and Pearson (2007) point out an important aspect in the concept of eco-innovations. For them, besides having a satisfactory environmental performance, a technology, product or service, has to be analysed in the context of the product life cycle and the supply chain.

[1] The Oslo Manual (OECD 2005) defines innovation as "the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organizational method in business practice" (where implementation means realization for use).

[2] MEI is a project for DG Research of the European Commission, carried out in collaboration with Eurostat, the European Environment Agency (EEA) and the Joint Research Center (JRC) of the European Commission. It offers a conceptual clarification of eco-innovation (developing a typology) and discusses possible indicators, leading to proposals for eco-innovation measurement.

Along the same lines, the final report to Europe INNOVA initiative on sectorial innovation informs that “eco-innovation means the creation of novel and competitively priced goods, processes, systems, services, and procedures that can satisfy human needs and bring quality of life to all people with a life-cycle-wide minimal use of natural resources (material including energy carriers, and surface area) per unit output, and a minimal release of toxic substances” (Reid and Miedzinski, 2008).

Taking back to the phase aspect identified by Schiederig et al. (2012), both Kemp and Pearson (2007) and Reid and Miedzinski (2008) explicitly identify the need for a full life cycle analysis and a thorough analysis of all input and output factors, with the aim of reducing resource consumption. We understand that a comprehensive definition of eco-innovation must include this aspect. It is not unusual that many products and services that are considered sustainable may have a production chain that ultimately invalidates the environmental benefits of its use (Kemp and Pearson, 2007; Kemp, 2009).

Discussion

When considering the use of eco-innovation and its effects in the design and generation of a product, there must be a conscious decision and commitment to incorporate environmental sustainability into the company's business strategy. However, for most companies, eco-innovation will involve a change in how they do business.

Nevertheless, this search for decoupling, i.e. a continuation of the economic growth vis-à-vis the reduction of the environmental impacts and the use of natural resources, still requires more eco-innovative solutions.

The eco-innovative product should also be designed to satisfy human needs and provide a better quality of life, minimizing the use of natural resources and the generation of emissions, waste and other environmental impacts.

Products go through a basic lifecycle that involves the stages of extraction of natural resources, the use of these resources in the manufacturing process, end-use and final disposal.

To maximize the product lifetime, that is, to extend its use phase, the producer can either make it more resistant (harder to break, for example) or easier to be repaired or upgraded. A sustainable end of life for the product can also be provided by creating a design where its disassembly could be more efficient. Raw materials could easily be reused, giving a longer life to these resources.

Products with enhanced durability would guarantee a better use of natural resources / energy and therefore have a lower environmental impact. Products with shorter lifetimes create more waste. After they are discarded, another product is needed in replacement, starting another cycle within a relatively short period of time. Of course to displace the notion of programmed obsolescence from “the business as usual” would require much environmental awareness and, perhaps, the involvement of civil society.

Eco-innovations can bring many added values, such as access to new emerging markets and the reduction of production costs along the value chain (UNEP, 2014b). When it comes to a proposal for extending product lifetime, both of these added values can be achieved. This new product can meet the demand of a market segment with customers who are interested and concerned about environmental issues, as well as its environmental and economic costs, during the whole life cycle. Processes can be optimized to extend product lifetimes, achieving the eco-innovation added value. In this sense, it could be important to adopt bar codes and labels providing environmental and social trusted information (in accordance with standards and legislations) regarding each stage of the supply chain (traceability) to customers.

Conclusions

This paper reviewed some literature on eco-innovation and decoupling, and, discussed how these could encourage the reduction of natural resources use and emissions, as well as waste generation. By presenting the relationship between the longer life design of products and eco-innovations, it exemplifies how this product attribute could be one of the eco-innovation concepts applied to the product design. It also aimed at relating eco-innovations to the decoupling proposal, pointing that the latter depends on eco- innovations.

Decoupling proposes a reduction in the use of primary resources of economic activities. As it is based on less use of material resources, energy, water and land, with the same amount of economic output. Eco-innovations result in reductions in environmental risks, emissions, pollution and other negative impacts of resources use.

As a more efficient way of producing more and better, using less natural resources, eco-innovations can be, at least in part, the means for a better alternative and through decoupling it can address the ecological crisis.

Further studies could be developed to clarify and strengthen the interrelationship between longer lifetime product projects, eco-innovations and decoupling. Empirical studies could also be developed to discuss eco-innovation's (in)direct impacts on longer lifetime products.

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Product durability and our understanding of nature

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Keywords: object oriented ontology; ecology; resilience; sustainability; cars.

Abstract: The study of product lifespans and product durability initially took a somewhat mechanistic approach, focusing very much on how to make products last longer. It was found however, that psychological and social factors were in many cases more important than purely technological factors in the decision to discard a product. A number of valuable contributions were made to this strand of thinking, many of which suggesting the need for a change in attitude. Such changes, however, would clash with countervailing pressures in society towards greater consumption. At the same time, it could be argued that such suggestions did not go far enough and that what is needed instead is a more complete revision of our relationship to objects and our understanding of the concept of 'nature' and how this has distorted our understanding of our role in the systems that prevail on our planet. It is important to understand that the concept of nature is in reality 'man-made' and that the artificial distinction between what is considered 'natural' and what is instead considered 'man-made' is increasingly unhelpful, as it creates a barrier to progress towards greater sustainability. By using a combination of ecological concepts and also concepts from recent philosophical thinking, this paper will explore these issues using cars as an example.

Introduction

The concept of sustainable consumption and production (SCP) has been attracting interest in both government and industry in the context of moves towards more sustainable societies. Industry is clearly a key player in this. Although it has traditionally blamed consumers for unsustainable product choices, this view was discredited by Hart (1997), who put responsibility firmly back in industry's court. At the same time, it is hard to deny that consumers share responsibility and that the relationship consumers have with products and the role these play in their lifestyle is a key issue in SCP. In response to this, environmentalists have often called for 'voluntary simplification' of our lives, something some individuals have been happy to adopt (Elgin and Mitchell 1997; Etzioni 1998). However, to most, consumption has become too closely associated with psychological factors such as identity and success (Jackson 2006). The main flaw, therefore, in many such debates– and one that besets many of our ideas in the environmental and environmental academic world – is that puritanism and frugality just do not sell. And yet, we are hoping to change the world with our ideas, which means convincing the majority that our ideas are worth trying out and will likely lead to a better life, not one of more hardship.

The economic growth model has become firmly embedded during the 20th century and with it a cycle of acquisition and disposal. Natural systems tend to work in cycles of growth and subsequent destruction, but the problem is that people and institutions do not see themselves as part of a natural system and there are always limits to the growth and destruction that any system can accommodate before a tipping point is reached (Walker and Salt 2006). We have developed the notion that human systems are somehow separate from other natural systems and therefore subject to a different set of – unnatural – laws. It is that we need to tackle.

A transition phase

For this reason we need to think in the first instance, perhaps, of a kind of transition phase, not so much in terms of just using less stuff as such, but less of better stuff – we need to replace quantity with quality. To give a crude example, rather than having a dozen handbags from high street shops, we have one Gucci handbag that becomes part of us, part of our image. Instead of having half a dozen H&M jackets, we have one Dolce et Gabbana jacket. When any of these quality items needs repair, we have them repaired and we grow with our treasured items as they grow with us, rather than disposing of them (Cooper 2005). Given that the environmental impact of a Gucci bag or D&G jacket is not significantly greater than that of its lesser equivalents, we reduce our impact, but I hardly think this constitutes hardship. The environmental impact debate is an interesting one; clearly the impact of a Rolls-Royce or Ferrari is greater than that of a Prius or Volt, but the impact of Toyota or GM is an order of magnitude greater than that of Rolls-Royce or Ferrari; the environment does not care about the impact of single items, but about the total impact of all of them.

While many in the environmental movement may think of a Ferrari, Gucci or D&G as the ultimate in consumerism, in reality, it may not be, as their products are not consumed in quantity. There are of course potentially difficult transitions to be made from mass production, mass consumption and mass employment to low volume production and consumption of high value durable goods and consequent employment of people in higher skilled jobs in smaller, more personalized facilities using more labour and creativity-intensive processes.

Our place in 'nature'

Once we get to this intermediate consumption stage - or ideally much earlier than that - we can then begin to tackle the more fundamental question of our place vis-à-vis what we call 'nature'; a term that is itself misleading in that it already separates us from the rest of creation. Morton (2010) suggests we should abandon that term and come to a more fundamental understanding of how we relate to the rest of creation and the impact of our actions and the feedback loops that will inevitably come back to haunt us if we get this wrong (Walker and Salt 2006). In object oriented ontology (OOO) as developed most recently by, among others, Morton (2010, 2013) and Bogost (2012) there is no hierarchy as such among what we find on our planet. Thus people, animals, plants, animate and inanimate objects are essentially of equal value and equally deserving of respect. It is this higher level thinking about our place in the world that often seems to be lacking in much of the environmental literature, as perhaps exemplified by the 'degrowth' literature (Georgescu-Roegen et al. 1979; Kallis et al. 2012). Many such works are still perhaps too closely linked conceptually with an 'economic' rather than an 'ecological' mindset (Krebs 2008).

Walker and Salt (2006) explain that natural systems can achieve equilibrium in various different states, each of varying stability. Some of these are more suited to us than others and these are therefore more desirable, at least for us; they ensure or facilitate our survival or comfort. However, the system, or indeed 'the planet' can exist in any of these states; any of these can be stable in its own way. So therefore we very often seek to stabilise a particular natural state because it brings those ecosystem benefits we are after. Even when we protect nature, we are therefore shaping it.

In reality, we humans have become totally intertwined with our technology in the broadest sense, such that humans and technology combined constitute our species (Malafouris 2013). Technology is a natural human characteristic in the way black and white fur is a characteristic of the giant panda. We would now struggle to survive without cooking our food, which requires the technology of controlling fire, kill much of our prey, which requires the technology of weapons and traps, or grow our crops, which requires the technologies of tools to work the soil and harvest plants. To a large extent we have co-evolved with our technologies – we make them suit us and adapt to them such that we increasingly suit them (Spyker, 2007). Our control of fire allowed us to keep predators at bay, change our environment and cook our food (Lipton and Bhaerman, 2011), similarly, our stone tools did a job for us and then we adapted to become better at making and using them (Malafouris, 2013; Reardon, 2013). What is true for fire and stone tools is true for all our technologies, all our creations ranging from a carefully dressed arrow-head to an iPhone. Technology is part of our nature and technology is thus a natural phenomenon and our relationship with our things should be understood that way.

On an ethical level, Kohak (1985, p. 35-36) explored the intrinsic value and our inherent moral obligations towards our artifacts:

> *"Artifacts are not only products but also gifts, be it of God or of Nature. …Though it*

might be my privilege to use that resource, that gift, it is immoral for me to waste it."

It is even possible that technology is used as part of our role in natural systems; nature will thus use our technological aptitudes to help it in its efforts to achieve equilibrium in the natural systems of which we are part. If this is indeed how humankind operates, with nature acting through us in a sociological and psychological fashion, then there is mounting evidence – even for those who still believe that we are somehow separate from, or even above the rest of creation – that in fact we are an integral part of nature and part of the natural processes used to maintain equilibrium – Gaia, if you like (Lovelock 2000) – and that we are therefore an integral part of nature's resilience and resistance. Indeed, Lipton and Bhaerman (2011, p. 209) argue that 'Humans, like every other organism in the biosphere, are here to support environmental balance, to buffer it, to sustain it, and to encourage harmony'. We are not, as some deep greens like to portray us, a blot on the landscape causing only harm and no good; we are natural. Lipton and Bhaerman add, however, like Field and Conn (2007), that we are unique in our awareness of our evolution and of our potential for change. We can therefore gain awareness of our role in maintaining harmony in natural systems and act accordingly; with foresight.

As part of this approach we also need to change our relationship with the objects around us. For example we need to start looking at objects as part of systems, rather than single entities, an approach to which cars lend themselves particularly well. As Jackson (2006) argues:

"There are few places where the symbolic character of material consumption is more naked to the popular scrutiny than in the case of the automobile…".

Automobility is also one of our least sustainable forms of consumption, which makes an exploration of our relationship with cars particularly significant in the context of SCP. Cars are themselves made up of some 15 000 components all working – ideally – in perfect harmony to deliver us personal mobility, identity, fun, while they are part of a system of conception, production, distribution and use that all contribute to the very complex system of 'automobility', or the automotive 'regime' (Geels et al. 2012). In this sense, an ecosystem approach is like systems theory. Meadows (2009) is a useful source here as she combined expertise in systems thinking with expertise in sustainability thinking. Natural and human-made objects become part of the same system in this context deserving of similar, though not necessarily equal attention.

It is important here to understand our position in time and space. In time, due to evolution, we are essentially a snapshot in a continuing process. 'Humans' are a point along an evolutionary continuum and it is very difficult to pinpoint at what point along that continuum we became human, and no longer humanoid, or ape, or whatever we choose to call it. Looking forward it will also be very difficult – except with hindsight – to determine at what point we will have evolved into another 'post-human' species. In terms of place, we need to realise that we are made up of the same atoms as everything else on this planet, including cars. The iron atoms in our blood are the same type of iron atoms as those in the Earth's crust, at the Earth's core, and in our car (Nieuwenhuis, 2014). This emphasizes the point made earlier, that in very physical terms, we are connected with everything around us, animal, vegetable and mineral – including our cars; we are all made of the same stuff.

Lipton and Bhaerman (2011, p.18) point out that '…the primary characteristic of life is movement'. To this extent, then, are cars 'alive'? Just think how easy it is to accept that the cars in the Pixar-Disney film *Cars* are animate; and, does it matter? Interestingly enough, some recent research has confirmed that most of us do not see cars as mere inanimate objects. The brain organizes things in terms of categories, or as us general linguists would call them 'semantic categories'. Research carried out at the University of California at Berkeley found that for many people, vehicles and animals fall into the same category (Reardon 2013, quoting Neuron, doi.org/j29); while Malafouris (2013) would recognize them as extensions of our own mind.

Shaping our environment, things

It is natural for us to want to influence, or change our environment. Like beavers with their dams, and termites with their mounds, we adapt our environment to suit us, as much as we adapt to our environment. In this context, to be presented with a product that discourages input from us is, in a very real sense, 'unnatural'. In the early years of the car, such input was normal (Franz, 2005). Franz (2005, p. 130) concludes that under the new culture that developed gradually during the 1920s and 1930s:

"In the eyes of the industry the perfect consumer did not tinker, but rather told the manufacturer what he or she wanted and then waited to receive the benefits of the 'holy trinity' of the modern age: science, industry and progress."

This is a model we are still familiar with today. We are inextricably linked with the technologies we use: '…, we create technology, technology affects us, and we in turn create or, rather, refine, technology' (Spyker, 2007, p. 67). But leaving this to a technological elite divorces us from that important and inherently human bond with our technologies. Spyker explains that it can in fact be 'spiritually comforting' to be pleased by an object (ibid., p. 84).

Assuming that premature scrapping is wasteful, or indeed even morally questionable, as Kohak (1985) argues, is it possible to make consumers more attached to their cars and thereby increase durability? The longer a product lasts, the less often it needs to be replaced and therefore the less often it needs to be produced, thus reducing overall production and resource use. At the same time, durable products significantly change patterns of consumption (Nieuwenhuis, 1994, 2008, 2014). Yet, products are often discarded not because of a lack of technical durability, but because the consumer has lost his or her emotional attachment to it (Chapman 2005; Muis 2006). Cars built for an expected lifespan of only 10-12 years, such as many from the 1960s, can be made to last many decades, if an owner can be found who is willing to build an emotional relationship with the product (Nieuwenhuis 2008, 2014). By exploring this type of relationship it may be possible to discover just how this could be used to build a model for sustainable consumption. Chapman's (2005) point that products are discarded because the owner has 'fallen out of love' with the object results in waste sites full of working machines and serviceable objects. Chapman (2005, p.9) blames the prevailing industrial model for this system of consumption:

"Consumers of the 1900s were not born wasteful, they were trained to be so by sales-hungry teachings of a handful of industries bent on market domination."

The US car industry with its once 'planned obsolescence' is a prime suspect. Chapman also blames an inability of products themselves to keep up with the speed of change in our world. Yet, the case of classic cars (Nieuwenhuis 2008), or the increasingly popular trend of modifying cars in various ways, does indicate an ability on the part of cars to adapt and 'grow' with their owners. The higher the initial cost, the more likely that this process of extending the ownership experience can be justified by an owner in line with the 'transition phase' suggestion made earlier. Perhaps with the higher purchase cost of electric vehicles (EVs), compared to their much lower running costs and inherently more durable technologies, EVs could be one way of achieving the intermediate phase of reduced consumption of higher value goods. The Tesla Model S may well be a good example of such a product. In fact, as the move towards the battery electric vehicle brings with it a move towards cars that, though emitting less CO2 in use, in fact contain significantly more embedded carbon (Hawkins et al. 2012), this need has never been more pressing.

Conclusions

I have tried in this discussion to bring together three strands of recent thinking that may help in building a new model of more sustainable consumption. It is increasingly thought that human evolution is closely intertwined with human technology; that our relationship with our things has in fact shaped us as much as we shape our things. This notion is perhaps most developed in Malafouris' Theory of Material Engagement (Malafouris 2013). Linking this with OOO, which maintains that everything is deserving of respect, including the objects we so readily dispose of, adds another key element to a model perhaps first hinted at by Kohak (1985). The final element concerns our notion of a concept of 'nature' as somehow separate from us. Morton (2010) suggests abandoning this idea. It creates a boundary between us and the rest of creation that in reality does not exist; the 'man-made' is as much part of ecological systems as anything else, including ourselves. This leaves us with a model whereby we and everything else around us share a common destiny of mutual interdependence. This could be leveraged to change our relationship with our objects such that we build more lasting relationships with them – the example of cars is explored above. By understanding this, we will gain a better understanding of how what we do impacts on other parts of the system and how feedback loops may then cause these impacts to impact on our ability to do what we have been doing, while also, perhaps as an intermediate step, improving the quality of our consumption at the expense of quantity.

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Methodologies for estimating actual lifetime distribution of products

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Keywords: actual product lifetime; estimation methodology; definition; durable goods; import of secondhand products.

Abstract: This paper introduces the methodologies for estimating actual product lifetime distribution. On the basis of a literature review, it was found that there are three common approaches for estimating actual product lifetime distribution in literature. Theoretically any of the three approaches can be selected for estimation as far as representative primary data is available, but unless accurate data are available the estimated average lifetime can vary. In addition, various different definitions of 'lifetime' can be defined and the lifetime definitions are determined by estimation approaches and primary data used for the estimation. The paper also introduces a simplified estimation method which does not require detailed information of product-age profile and enables estimation from the total number of in-use products that is easier to investigate.

Introduction

Product lifetime is important information for understanding progress toward sustainable consumption and estimating the stocks and end-of-life flows of products. A certain amount of actual lifetime data is available in literature; however, it varies in the definition and the employed estimation methods. This paper discusses the characteristics of methodologies for estimating actual product lifetime distribution on the basis of literature review. The paper also introduces a more simplified method for easier estimation of actual product lifetime distribution.

Common approaches for estimating actual product lifetime distribution

Actual lifetime differs among individual products (i.e. owners); therefore, lifetime of a particular product-type is expressed as a distribution. Three common approaches for estimating actual product lifetime distribution were found in literature (Table1, Oguchi et al., 2010).

These approaches estimate product lifetime distribution based on the past sales and the number of in-use products or discarded products with their product-age profile. The large differences among the approaches are the required information and the directly estimated distribution. The approach (1) estimates the discard rate distribution which directly represents lifetime distribution. The other two approaches estimate the survival rate distribution or the failure rate distribution. But theoretically they can be converted to the discard rate distribution.

The approaches (1) and (2) are often used for automobiles and consumer durable goods. The approach (3) is often used for buildings because it needs no sales data which is usually hard to obtain for buildings.

Any of these three approaches can be selected for the estimation as long as good primary data (i.e. complete dataset) is available such as the case of passenger cars. In the case of electrical and electronic equipment, however, there were a few years difference in the estimated average lifetime between approaches. These differences can be attributed to biases of sample surveys, because technically similar results can be obtained approaches if accurate data is available as confirmed from the case of passenger cars. We must be cautious about the representativeness of primary data when the estimation is based on a sample survey.

Various 'lifetime' definitions

Various different definitions of 'lifetime' can be defined according to the starting and ending points for the periods (Figure 1, Murakami et al., 2010). Some of the lifetime definitions are completely different from others, so we must

Approach	Required data (number of…) End-of-life	In-use	Sales	Survey method for primary data (definition of estimated lifetime)
1. Calculate discard rate distribution for a certain period	x (for each age)		x (time-series)	• Survey of collected EoL products at facilities (total lifetime) • Questionnaire to consumers who discarded products (duration of use, or possession span)
2. Calculate survival rate distribution at a certain time point		x (for each age)	x (time-series)	• Questionnaire to consumers to ask the number and product age of in-use products (domestic service lifetime)
3. Calculate failure rate distribution for a certain period		x (for each age, at least two time points)		• Questionnaire to consumers to ask the number and product age of in-use products (domestic service lifetime)

Table 1. Common approaches for estimating actual product lifetime distribution. Source: Oguchi et al., 2010.

distinguish these definitions clearly to avoid misunderstanding and misuse of reported or estimated actual lifetime data. Four major definitions were found in the literature; 'total lifetime,' 'domestic service lifetime,' 'possession span,' and 'duration of use.' The former two basically denotes how long a product stays in society, and the latter two denotes how long a single owner possesses or uses a product. The most common definition in the literature was 'domestic service lifetime' and another common one was 'duration of use.'

The 'lifetime' definition is determined by the estimation approach and/or primary data used for the estimation. For example, if the lifetime distribution is estimated by using the approach (1) based on the investigation of the number and age-profile of collected end-of-life products at recycling facilities, the estimated lifetime should be 'total lifetime.' If the estimation is done by using the approach (2) based on a questionnaire survey to consumers asking how long they use their old products, the estimated lifetime should be 'duration of use,' or 'possession span.'

A simplified method for estimating actual product lifetime

The method and a case of passenger cars

To apply the approaches introduced above, it is necessary to conduct some extensive surveys to obtain detailed information on the age profile of in-use products or discarded products. Because this is time-consuming and cost-intensive, this should be one big obstacle that prevents the collection of actual product lifetime data. Regionally- and temporally-static product lifetime is often assumed in material flow analysis and lifecycle assessment based on the results from limited studies or educated guesses. Inappropriate assumption, however, may cause a large inaccuracy in the results; therefore, more precise data on regional differences and temporal variations in the actual product lifetime needs to be estimated.

In this context, the author and a colleague proposed a more simplified method for estimating product lifetime in different countries and years which does not require detailed information of product-age profile (Oguchi and Fuse, 2015). With this method, product lifetime distribution is estimated on the basis of mass-balance of products. Assuming that the survival rate distribution of products follows any statistical distribution function such as the Weibull distribution function, the survival rate distribution can be determined so that the total number of in-use products calculated from past sales and the survival rate distribution consists with the observed number. Thus, average lifetime can be estimated only from the past sales and the total number of in-use products, which is easier to investigate.

To apply this simplified method, unknown parameter should be only one, i.e. practically parameters other than 'average lifetime' must be given. The author and a colleague examined the possibility of applying a constant value to the distribution parameter by using passenger cars as an example. It was assumed that the lifetime distribution follows the Weibull distribution function with two parameters: average and shape parameter. Then the applicability of a constant value to the shape parameter was examined.

Distribution shape slightly changed according to the value of the shape parameter, but it appeared that the sensitivity is not so high. Thus, average lifetime was estimated by assuming shape parameter to be a constant value 3.5, which is the average value of 18

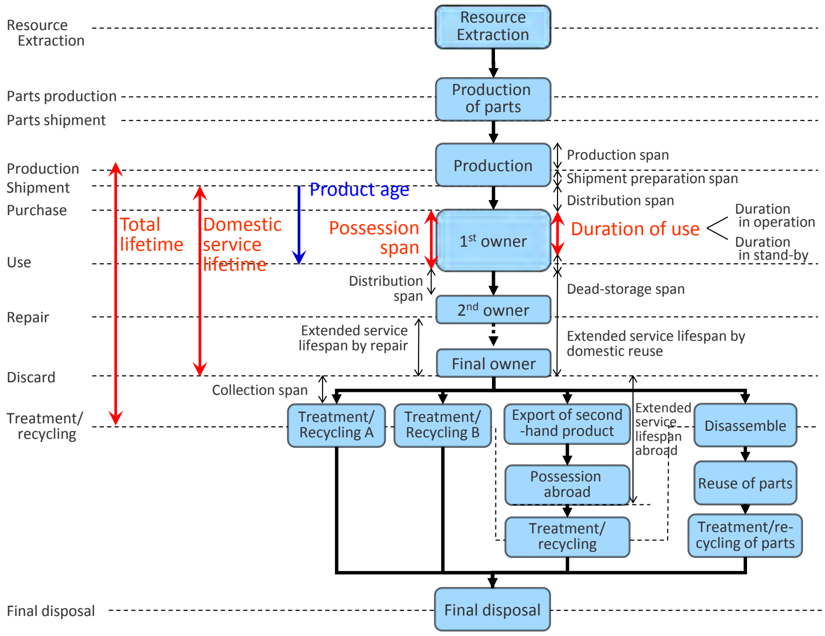

Figure 1. Various 'lifetime' definitions. Source: Murakami et al., 2010.

countries. As a result, the estimated average lifetime with the constant shape parameter was almost the same as the original estimates for each country. Reasonably good approximation results were obtained suggesting that the shape parameter can be replaced by a constant for various countries in the case of passenger cars.

Taking passenger cars as an example, the proposed method was applied for estimating the longitudinal trend in the average lifetime from 2000 to 2010 in 20 countries. Figure 2 shows the results. The estimated lifetime is defined as 'domestic service lifetime.'

The estimated average lifetime differed greatly among the countries from 9 years to 23 years. The average lifetime had been almost stable in Austria, Belgium, Brazil, Germany, Ireland, Italy, Spain, Sweden, and the UK. In other countries, the average lifetime had been increasing. Especially large increases (2–5 years) was seen in Australia, Finland, Switzerland, South Korea, and the United States. These results suggest that consumer behaviour on using and discarding passenger cars differed among countries and changed over the years even in developed countries.

The introduced simplified method can be used for estimating actual product lifetime in various countries and years more easily. Based on the results, we can understand the differences in actual product lifetime between countries and its change along years.

Applicability to other product types

It is also useful if the proposed method can be applied to other product-types such as electrical and electronic equipment because detailed information on the number of in-use products for each product age is usually not easily available. Since the sensitivity of the estimated average lifetime to the value of the shape parameter is low as noted previously, the method may be applied for other types of products when the values of the shape parameter are not significantly different.

The possible applicability can be discussed based on two Japanese studies. Oguchi et al. (2006) estimated parameters of the actual lifetime distribution (average 'domestic service lifetime' and shape parameter) of various types of electrical and electronic equipment in 2003. The estimation was done by using the estimation approach (2) based on a questionnaire survey to 9000 households and 5000 enterprises on the number and the product age of in-use products. According to the results, the estimated shape parameters differed from 1.7 to 3.3 for 22 product-types. However, the similar values were obtained for the average lifetime when the shape parameter was replaced by a constant value within the range of 1.7–3.3. In addition, Tasaki et al. (2001) demonstrated that the shape parameter can be replaced by a constant value over time by using the data for seven common home appliances. These results suggest that it would be possible to apply the proposed simplified method to various types of electrical and electronic equipment in one country.

There is no sufficient data of actual lifetime distribution of those product-types for verifying the applicability of the simplified method to electrical and electronic equipment in various countries. The application of the proposed method would be further extended by obtaining empirical data on lifetime distribution for other countries and emerging technologies as well.

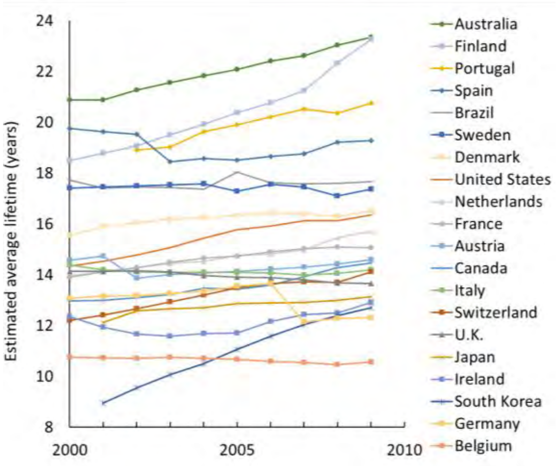

Figure 2. Regional and longitudinal trend in average lifetime of passenger cars estimated by the simplified estimation method. Source: Oguchi and Fuse, 2015.

A future challenge: estimation taking into account imported second-hand products

High incidence of imported second-hand products may be likely in developing countries. The proposed simplified method can be applied to such countries; however, the number of imported second-hand products needs to be taken into account with consideration of their age profile. Imported second-hand products are not included in sales data but are included in the number of in-use products. Unless the number of sales is adjusted to include the imported second-hand products, average lifetime will be overestimated because the number of sales is undercounted. This is quite challenging because obtaining quantitative data for the age-profile of imported second-hand products is quite hard. A possible solution is to assume the age-profile of imported second-hand products as a certain distribution function and include the imported second-hand products into the number of sales by taking into account the age-profile. If the applicability of this approach is verified, the method can contribute to assessing how the product lifetime is extended by international reuse.

Conclusions

This paper discussed the methodologies for estimating actual product lifetime distribution. There are three common approaches used for estimating actual product lifetime distribution in literature. Theoretically any of the three methods can be selected when representative primary data is available, but unless accurate data is available the estimated average lifetime can vary. In addition, various different definitions of 'lifetime' can be defined. As the lifetime definitions are determined by estimation approaches and primary data used for the estimation, an appropriate methodology needs to be selected according to the purpose of utilizing the estimated lifetime data. A simplified estimation method was also introduced by taking passenger cars as an example. The method would contribute to obtaining more data in various countries and years. The applicability of the proposed simplified method to other products was also discussed for the case of Japan; however, future research is needed on other countries' cases.

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Product development and supply: help or hindrance to clothing longevity?

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Keywords: clothing supply chain; new product development; clothing longevity; trade-offs.

Abstract: Designing longer lasting clothing helps to reduce unsustainable levels of product disposal and subsequent waste. This has led to a call for retailers to enhance clothing longevity, supported by new business models to reduce any impact on competitiveness. While some research suggests that a significant proportion of consumers would buy longer lasting clothes, this view is not necessarily accepted by industry strategists. This paper, which reports on research undertaken for WRAP (Waste and Resources Action Programme), explores conflicting priorities between commercial and sustainable practice, and problematic trade-offs in the supply chain between commercial, technical and design aspects of reducing the environmental impact of clothing. The study adopted a mixed methodology, incorporating qualitative interviews and a survey, and encompasses views of retailers, manufacturers and suppliers from different segments of the UK fashion market.

The findings confirm that retailers and brands drive the new product development process and set standards for their supply chains, but globalization, product churn and testing regimes challenge the critical path schedule. Although current tests confirm product quality (WRAP, 2013), there is a perception within industry that designing for longevity increases testing, inflating the risk of failure and extending lead-times, resulting in a mismatch between cost, time and longevity priorities that limits adoption of design for longevity. Meanwhile, clothing longevity is not perceived to add value for many consumers and therefore is not prioritised. While it is technically possible to enhance clothing longevity, the findings demonstrate empirically that this deviates from current commercial drivers of global clothing supply chains. By combining different perspectives on supply chains, new product development and sustainability, inherent conflicts are revealed.

Introduction

Designing clothing that lasts for longer than current norms helps to reduce excessive, unsustainable product disposal and waste. This has led to a call for retailers to enhance clothing longevity, recognising that this may need to be supported by new business models to reduce any impact on competitiveness (WRAP, 2012). Although over a third of the population claim that they could buy more clothes that are ‘made to last’ and would like to do so (WRAP, 2013), there is limited evidence that this view is shared by industry strategists.

The paper uses evidence from interviews and a survey with clothing industry stakeholders to explore the conflicting priorities, perceptions and tensions between commercial and sustainable practice in this emerging field, and discusses the drivers exerted on the supply chain and the commercial, technical and design aspects of reducing the environmental impact of clothing.

The research on which it is based was undertaken for WRAP (Waste and Resources Action Programme) and aims to identify ways to address problematic trade-offs and make recommendations for industry and future research.

Literature review

Longevity of clothing takes into account durability as well as user behaviour and wider socio-cultural influences (Cooper, 2010). Drawing upon this understanding of longevity, a review of recent studies explored issues associated with clothing longevity from technical and consumer perspectives, as well as the commercial aspects of designing new clothing products and the clothing supply chain.

Clothing longevity: technical and consumer considerations

Garment waste accounts for around 5% of total UK household waste, even though carbon, water and waste footprint studies indicate that extending the useful life of clothing, assuming this reduces product sales, could effectively reduce negative life-cycle impacts (WRAP, 2012). Most of these impacts are embedded in clothing production, rather than its use and care, and research suggests that increasing the useful lifetime of clothing by one third could reduce its environmental footprint by over 20% (*ibid*). However, at present a range of fabric, component, construction and colour failures shorten clothing lifetimes, even though such failures are often avoidable.

As a result, policy attention has turned to reducing the environmental impacts of clothing by designing garments to last for longer. Designing products for longer lifetimes is a UK Government policy objective (HM Government, 2013) and a priority in the Sustainable Clothing Action Plan produced by WRAP. An assumption that longevity need not have a negative commercial impact if appropriate business models and pricing strategies are adopted is consistent with government policy (HM Government, 2013), but appears to be at odds with the view of some industry strategists.

The latter point to alternative research into consumer behaviour and expectations which suggests that consumers make increasingly regular purchases (Fisher *et al.*, 2008) of low price, lower quality (Leonard, 2008), fast turnaround clothing (Black, 2008). Concern surrounding issues associated with fast fashion is, however, increasingly evident from some retailers, consumers and media commentators (Muton, 2012). Concerned consumers, dominated by mature women who favour durable clothing and are influenced by the relationship between price, quality and value (Mintel Oxygen, 2011; WRAP, 2012; Fisher *et al.*, 2008), create an opportunity to increase the longevity of (in particular) classic items and schemes for clothing buy-back and re-use (WRAP, 2012).

Increased garment longevity would clearly require changes in industry practices. For example, tests of product longevity and extended wearer trials can help product developers to make decisions that avoid or delay garment failure (Cooper *et al.*, 2014), with extreme tests of durability for some performance items and other recent advances in testing now available that could fit better with the supply chain's speed and cost imperatives and changing consumer care practices (Shellenbarger, 2001; Annis, 2012; Cooper *et al.*, 2014).

New product development and the clothing supply chain

New product development (NPD) of clothing incorporates idea generation, market screening, concept and technical development and commercialisation, leading to the design and specification for each clothing item (Swink, *et al.*, 2010). In practice, the process may cause delays in the supply chain through indecision associated with multiple interests, conflicting priorities and functional constraints of the design and technical staff, marketing, purchasing, production, sourcing and finance roles of retailers and brands, compounded by the trend for rapid proliferation of products and globalisation of supply.

The fast fashion approach addresses these conflicts (Cachon and Swinney, 2011) with two system components: cost effective manufacture and rapid new product introduction, in which the design selection process is shortened and emphasis on materials testing reduced (Marion, 2013). Consequently, much fast fashion is based on minor product adaptations during season, supported by postponement, modularisation and fabric platforms, rather than new designs (Cachon and Swinney, 2011; Caro and Gallion, 2007; Barrie, 2013).

Influenced by the spread of fast fashion, it might be expected that commercial imperatives would include fast decision making, shorter lead-times, reduced sampling, and greater use of virtual technologies to minimise additional sampling (Khan *et al.*, 2012). In practice, design and brand integrity results in slow decision making and added product testing (Brun and Castelli, 2008; Pisano and Adams, 2009), which fosters a resistance to innovative design practices that could shorten the design or manufacturing process (Oxborrow, 2014). Indeed, Abecassis-Moedas (2006) found that close-to-market design decisions and waiting for information from market or component tests inhibits creativity and delays the critical path, leading to unsustainable practices in sourcing and logistics (Khan *et al.*, 2012). Early supplier involvement in the design process, co-design and modularity can improve on time and cost performance (*ibid*), but in reality may merely enable a retailer to compensate for increased global sourcing lead-time. Meanwhile Aage and Belussi (2008) found that clusters of firms better acquire fashion and technical knowledge, but supply chain clusters have fragmented while retailers have assumed control of the design role and direct responsibility for outsourcing production (Abecassis-Moedas, 2006).

Melnyk *et al.* (2009) concluded that supply chain metrics favour short-term cost elimination, rather than strategic priorities. Low cost global sourcing has increasingly become the industry norm (Hameri and Hintsa, 2009; Lowson, 2002; Scheffer, 2012) and often results in short-term supplier selection decisions and frequent supplier switching (Harland *et al.*, 2005; Tachizawa and Thomsen, 2007). The cost focus also increases the potential for supply chain risk, including external environmental and sustainability risks which can affect economic, social and environmental performance (Christopher *et al.*, 2011). Barriers to the adoption of sustainable supply chain practices include lack of transparency, data reliability and influence over upstream suppliers (Rauer and Kaufmann, 2015). Correspondingly, risk mitigation factors are limited because of high demands on data, collaboration and time (Christopher *et al.*, 2011) while commercial resilience depends on building social capital, such as brand reputation (Rauer and Kaufmann, 2015).

Methodology
A mixed methodology was used. This included 21 semi-structured interviews with strategic managers and operational professionals of key clothing retailers and suppliers. An online survey administered to a database of 120 retailers, brands, suppliers and clothing/textiles manufacturers secured a further 21 responses. The dual approach was used to capture comparable data from a wider sample to explore a range of commercial, technical and behavioural aspects of producing clothing to last for longer than current norms. Respondents covered discount to luxury market levels, fast fashion and classic items, within the UK clothing production-distribution chain: all were based in the UK, though most have global supply chains.

Findings and analysis
The findings from interviews and surveys are presented below, covering themes identified during the research, and structured in this paper around aspects of sustainable and commercial strategy; industry perceptions of consumer expectations; aspects of new product development and testing, and implications for supply chain management.

Environmental and commercial sustainability
Most respondents have strategies in place for sustainability of their clothing design and/or production. Sustainability measures included selection of appropriate materials and reducing energy and water consumption, however, rather than addressing product lifetimes. For some retailers and brands, clothing longevity is considered instead as a value-statement for consumers, embodied in print, trim and manufacturing quality; finishes to prolong clothing life; guarantees to customers of product lifetime (durable items) or number of washes (intimate garments), and comparable wash/wear tests to demonstrate value. However, there was uncertainty over how clothing longevity can be measured and communicated to consumers, and whether this strategy could win market share.

Customer perceptions
Manufacturers appear to expect their products to last longer than do their retail customers, with fast fashion predictably having the shortest lifetime expectancy. Overall, respondents expected most garments to last 1-2 years, with coats and suits lasting over 5 years. This gap is explicit for jeans, for which fast fashion lines have a predicted life of 1 year, compared to 5 years for high street classics. Respondents perceived that consumers in value-conscious high street and low value markets might buy clothing designed, tested and guaranteed to last for longer, and may pay more for this, whereas. fast fashion consumers would not.

Longevity initiatives and testing
Testing of materials and components is done by specialist testing facilities at key points in the global supply chain, primarily during NPD, rather than for replenishment cycles. Most tests are designed to ensure products are 'fit for purpose' at the point of sale; longevity of components or finished products is not routinely tested for, or may be retrospective, (i.e. after products arrive on sale) to underpin durability claims or inform subsequent practice.

Retailers and suppliers indicated that current performance criteria achieve appropriate product quality for their consumers and markets, and that testing is reduced for small volume, fast fashion orders. Tests for longer lasting clothes, they suggest, could potentially include additional or revised tests to increase confidence in product performance, improved labelling and information for consumers. To increase product durability *per se*, respondents suggested improvements to yarn and fabric specification, enhanced technical knowledge, and improvements to dyeing, fabric treatment, and garment construction.

NPD implications
Retailers suggested that most designers prioritise fashion, with an emphasis on style and colour, but that they are expected to have an awareness of performance standards. To explain the apparent general decline in product quality, retailers said that to meet price points their top priorities would be to downgrade garment style features and materials used, and that commercial decisions would often over-ride quality if garments failed to meet testing standards. That said, in higher end markets such products are more likely to be rejected and improved.

Garment longevity was said to depend on sourcing criteria for the yarns and fabrics for each product and on the construction methods on individual specifications. Interviewees and survey respondents indicated that, for many products, longevity is not generally considered a high priority, and consequently such practices are not being adopted consistently within the industry. One suggested designing in new finishes and technologies such as improved abrasion, anti-pilling, stain resistance, soil or stain release and anti-microbial treatments to improve product longevity. However, the survey also revealed that industry practitioners believe that clothing longevity tests could increase garment costs by up to 5% for some products and add up to 2 weeks to garment lead-times, confirming suggestions that improving garment construction to last for longer could increase costs (WRAP, 2013).

Supply chain implications
Retailers expect to receive test reports and performance information on yarn, fabric and finished garments at the product development stage, including a written assurance that the yarn/fabric is suitable for the intended end use. In reality, it was said that this level of confidence in testing and quality information is often built up over years of experience, in established buyer-supplier relationships. This sense of trust and shared ownership of the final product was most evident in suppliers to the middle and higher levels of the market. New or remote suppliers may be less familiar with working procedures and fail to supply the required confirmation. Garment suppliers normally pay for tests on their products, although costs are sometimes passed on to retailers.

While retailers (or brands) drive clothing performance standards, in practice the global nature and fast pace of the industry means that they are not always in full control of yarn and fabric selection, while product proliferation, shorter selling seasons and lead time pressures make it more difficult to test new fashion products within the constraints of the critical path.

Discussion
While clothing companies need to adopt a strategy that embraces design, production, sourcing, testing and communication to support sustainability (Fletcher, 2008) and satisfy consumer demands (Khan *et al.*, 2012), our findings suggest an industry perception that designing for longevity involves more costly and lengthy sampling and testing, increases the risk of garment rejection prior to sale and increases lead-times. On closer inspection, design for longevity adds to the pre-existing (and so far unresolved) conflict between the drivers of cost pressure, on the one hand, and design integrity on the other.

While superficially the extra cost and time required to design more durable products challenges the cost driver, it is clear that the effects of cost-centred decisions are more profound. The lack of technical skills and knowledge required to design for longevity is exacerbated by globalisation, supplier switching and fragmentation of industry clusters (Aage and Belussi, 2008).

Even in markets where cost is less dominant, design integrity is a barrier to adopting design for longevity, which is perceived to limit fabric, component or garment construction options, require finishes that affect style features and involve additional tests that slow an already problematic product development cycle (Oxborrow, 2014). Furthermore, there is a lack of confidence in data, collaboration, and initiatives that could shorten design decisions (Marion, 2013) but facilitate design for longevity (Fisher, *et al.*, 2008).
Furthermore, while retailers and brands argue that consumers are satisfied with garment durability, this stance does not fully account for the other aspects of longevity that could be better aligned to design integrity, giving consumers reason to develop emotional attachment to their clothes and thus reducing premature disposal.

There is a persistent and systemic mismatch between cost, time and longevity priorities that compromises the transition to longer lasting clothing. This is exacerbated by the strategic and operational behaviours of retailers and suppliers and their interpretation of consumer behaviours and preferences. Expecting retailers and brands to adapt their NPD processes to design and test for product longevity remains problematic, especially without better understanding of clothing longevity - beyond durability - from both a consumer and commercial perspective.

Conclusions

While it is technically possible to enhance clothing durability, the primary obstacles were revealed through this study to be systemic and rooted in the commercial drivers of global clothing supply chains. The research has added empirical data to theoretical ideas, bringing together different schools of thought on clothing supply chains, design and product development, and sustainability. The findings highlight a conflict between commercial imperatives such as cost, time, design integrity and sustainability imperatives, including increased product longevity. Ultimately, there is no clear driver for mainstreaming design for clothing longevity, particularly from a commercial perspective; hence acceptability currently appears low, while limited time and resources, conflicting priorities and perceived risk limit more widespread uptake. The cost-benefit trade-offs are not fully appreciated, nor are the broader aspects of clothing longevity.

The findings are based on a relatively small sample, with implications for generalisation.. This confirms a pressing need to understand better the commercial implications of incorporating clothing longevity into NPD and supply chain practices. Understanding consumer perceptions and opportunities for new business models is critical to stimulating change in the clothing supply chain. It is recommended that businesses consider the preferences of their own target consumers and evaluate the cost-benefit and reputational implications of selling potentially fewer garments that last for longer than at present. In the long term there is a critical need for the industry to re-evaluate its strategic priorities and implement aligned supply chain and NPD practices.

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Print to repair: opportunities and constraints of 3D printing replacement parts

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Keywords: 3D printed parts; IP; replacement parts; product repair; spare parts.

Abstract: 3D printing and allied digital making technologies (scanning and laser cutting) have over the last 20 years become firmly established in many product development and prototyping settings. 3D printing, in particular, has developed dramatically resulting in a multitude of low-cost desktop printers that now appeal to a broad spectrum of users from design and manufacturing professionals to individual makers. The maker movement (craftspeople, tinkerers, hackers, hobbyists, inventors and business start-ups) has been central to its development.

Makers have played a leading role in the development of low-cost 3D printers. A desire widely held by advocates for 3D printing springs from the transformative opportunities afforded by the technology that includes printing replacement parts for product repair, refurbishment and customisation. 3D printers have an inherent ability to replicate parts derived from a digital file. Since the inception of the maker movement, an ethos has been to enable the hacking, repairing and repurposing of products, thereby prolonging product lifespans.

Does 3D printing offer a viable alternative to providing spare parts to prolong product lifespans? This paper examines print to repair examples utilising personal low-cost desktop 3D print and print to order services. It discusses current constraints and opportunities that currently impact upon the wider adoption of print to repair activities. Examples, including the author's own projects, illustrate the benefits and emerging opportunities for product repair, as well as current technological and legal constraints.

Introduction

Conspicuous production

3D printing and allied digital making technologies are now being widely applied to purposes beyond their original use as a rapid prototyping product development tool. Although 3D printing has been around for over twenty years, it is now emerging as a disruptive technology (Manyika et al., 2013). It is disruptive because it enables a broader range of business and individual makers to design, build, distribute and sell products and services, thereby sidestepping the barriers of traditional manufacturing, marketing and distribution. Business models are being inverted and democratised by enabling consumers to remix, customise or create new products. Aided by Web 2.0 platforms, such as Etsy, eBay, GrabCAD, Shapeways and Thingiverse, individuals can now connect to a vast distributed network to market digital designs and 3D printed products. With lower entry barriers to creating and sharing, makers are now afforded incredible powers of production and distribution by new technologies and a globalised economy (Anderson 2012).

> *"The current evolution of the maker movement is an early signal of the future business landscape. While we are still adjusting to and making sense of the first wave of digital disruption led by the digitization of information, disruption is now moving into the physical and product level"* (Hagel, et. al. 2014, p17).

Rise of the Replicators

3D printing is an additive manufacturing process. It prints by adding or solidifying small amounts of material at a time. These printers enable the creation of physical artefacts from a

Advantages	**Description**
Tooling	No tooling is required for moulds, jigs or formers to create parts of varying complexity. This can contribute to lower costs as parts do not need to amortise investment in tooling.
Low cost tooling	For batch production runs of spare parts, 3D printing can be used to produce moulds (Bridge or Rapid tooling) for investment cast or injection-moulded parts.
No cost penalty for complex parts	Complexity is free. 3D printing is ideal for complex forms with voids, undercuts and internal geometry, such as ducts and vents. This is a clear advantage compared to other manufacturing processes where complex parts must often be fabricated out of multiple parts and materials and/or the commissioning of expensive tooling.
Variety of materials	Personal desktop machines commonly use ABS and PLA plastic polymers to create dimensionally acceptable and robust components. 3D print service bureaus (Shapeways, 2015) will offer dimensionally accurate and a greater range of higher performance engineering materials, including metals ceramics and flexible polymers.
Parts design	Designing parts for 3D printing is simpler compared to injection moulding or die-casting processes. The designer does not need to consider design constraints such as draft angles, undercuts and consistent wall thickness and edge radii for mould flow.
Parts revision	A part design exists as a constant Beta that can be modified, improved and changed as required. As there are no tooling and minimal set-up costs, only the digital file requires revision.
Parts on demand	An inventory of spare parts does not need to be stocked for anticipated demand.
Printing parts at site	3D printers can be located close to the location where parts are required. A recent unusual example is testing 3D printing on the International Space Station (NASA, 2014).
Recreating parts	3D printing of replacement parts is already established in specialist automotive and aerospace industry sectors where spare parts no longer exist. This typically includes ducting, seating and lighting components.

Table 1. Advantages of 3D printed parts.

variety of materials using digital files that can easily be shared through websites and email. Recent improvements in the technology now mean that operating parts can be produced utilising a range of high performance plastic, metal and ceramic materials. While personal low cost desktop machines lack this capability, the range and performance of materials continue to improve (Torabi et al., 2014).

Fused filament is the most common technology utilised by such printers. A plastic filament, often Acrylonitrile Butadiene Styrene (ABS) or Polylactic Acid (PLA), is extruded through a heated nozzle that follows a precise tool path to create an object in layered increments.

The maker movement, consisting of a community of craftspeople, tinkerers, hackers, hobbyists, inventors and business start-ups, has played an important role in the development of personal desktop printing. This journey is marked from the open source Reprap 3D printer, a project that originated in 2005 for dedicated enthusiasts, to the current crop of out-of-box printers that appeal to a much broader community of makers.

Replicating parts

3D printing offers significant opportunities for creating replacement parts. It is particularly suitable for one-off or small batch production runs that enable parts to be produced on demand quickly and at low cost. This inherent benefit of the technology was recognised early on with the Reprap which was conceived to self-replicate components to build other Reprap printers (2014). Since its inception an ethos of the movement is to enable the hacking, repairing and repurposing of products. This is summed up in the light-hearted manifesto titled the "Maker's Bill of Rights" to accessible, extensive, and repairable hardware. *"If you can't open it, you don't own it"* (Jalopy, 2005, p 154). Specific advantages for 3D printing replacement parts are defined in Table 1.

Notwithstanding the clear advantages for 3D printing spare parts, there remain disadvantages with the current technology. This is especially true for the many lower-cost desktop machines that have become available in the last few years. Personal desktop 3D printers are still in an adolescent stage of development (France, 2014). Few have the performance and reliability that we expect from other equipment. Printers are often temperamental and require surveillance while printing. Parts will often fail to print as planned, requiring modifications to the part design and machine settings. Personal desktop machines are limited by material choice. ABS and PLA plastics are available in a limited range of coloured filaments. Print characteristics of each material, such as shrinkage, warping and surface texture will often vary. Preparing or creating a part design requires knowledge and skill. Additionally, scanning technology is still in its infancy. Raw scans inevitably require cleaning up in 3D software. Creating or reverse engineering a part from scratch requires knowledge and 3D modelling skill. Unlike the ubiquitous inkjet or laser paper printer, 3D printers are inherently more complicated that the keyboard command 'ctrl+p'.

Intellectual property

A distinctive feature of 3D printing is that objects can be copied and shared. This raises concerns regarding intellectual property (IP), but how a part is protected remains uncertain since digital property rights are a poorly defined field (ACIP, 2014). A 3D printed part exists as two separate elements - a physical part (the object) and the digital file. Copyright exists automatically with a digital file (by virtue of authorship), but it is uncertain how it applies to a 3D printed functional part (Weinberg, 2015). However, a part may be protected as a Registered design and in certain circumstances, if the part is independent from other components and has a new functional advantage a patent may be sought to protect it. In Australia, using a 3D printer to make a part that is identical or substantially similar to a registered design is an infringement (Miller, 2014). The Australian Designs Act states "Registered designs protect the visual appearance of a product, in accordance with the Act" (Designs Act, 2003) While sharing the data to print the same part is not an infringement of design rights it may infringe copyright or other rights.

Additionally, with these specific regard to spare parts, where parts are used to restore the external appearance of a product, must fit with other parts, or are purely functional designs they are not protectable (L. Miller. personal communication, 20 February 2015).

Clarity regarding IP protection is missing. Disruptive digital technologies such as 3D printing highlight these inadequacies. In Australia, the Advisory Council on Intellectual Property (ACIP) is currently reviewing registered design law. In the course of their review they found:

> *"In particular, technology is transforming the nature of design and making 'virtual' or software designs more important, but design protection is tied to whole, physical products. Further, 3D printing and scanning technologies enable online circulation of designs but such activities are not captured by design law and, in at least some cases, copyright may be of no assistance".* (ACIP, 2014, p. 2)

In Europe and the United States, the law and how it applies on these matters varies. This adds complexity to how IP is managed in the common situation of a file being hosted on a web server in one country but utilised for printing parts in another. Web-based file sharing platforms and 3D printing bureaus have similar concerns. A leading 3D printing bureau, Shapeways request that creators of 3D designs do not infringe other people's IP rights. They focus upon copyright and have a takedown procedure for designs that may infringe IP (Shapeways 2015). Thingiverse is described as, "a thriving design community for discovering, making, and sharing 3D printable things" (Thingiverse 2015) and encourage users or use creative commons licensing. Another web based service, Kazzata, claims to be "an online spare part marketplace and CAD file repository, making it dramatically easier to access obsolete or rare parts via 3D printing" (Kazzata, 2015). The service attempts to crowd source designers and engineers to 'reconstruct' spare parts based upon user requests though there are few examples and little evidence of much activity. Kazzata's terms-of-use only briefly mention IP. Their emphasis is exemption from product liability arising from warranty claims and indemnification.

Discussion: print to repair

Examples of 3D print to repair parts illustrate these points regarding technology and IP matters.

Enhancing parts: kMix blender cap

The Kenwood kMix BLX51 blender cap has a screen-printed 'K' trademark which is an important identifying feature of the product. The BLX51 blender is protected by European design registration (OHIM, 2015). The replacement cap reproduces the original part's geometry but differs in colour, texture and finish and omits the trademark graphic. This partly reflects a limitation of reproducing parts on a desktop 3D printer. The reproduced cap is visually incongruous compared with the original, but maintains a consistency in form in order to fit with the existing product (Figure 1).

Figure 1. kMix replacement cap (Photo: Author).

As a strategy to enhance the functional use of the blender cap and to sidestep any IP infringement, the part design was changed to incorporate a ring pull (Figure 2).

Figure 2. Enhanced replacement cap with ring pull. Source: Author.

Figure 3.a and 3.b illustrates a further change to the cap by incorporating a citrus juicer and funnel which enables liquids to be added to the blender whilst in operation. Both modified designs make it less likely to inadvertently drop the cap into the blender, a fate that befell the original part.

Reproducing external features of a part where it needs to mate with an existing product is important but this brings into question how similar a 3D printed replacement part may become to the original part. By substantially changing features of the design where fit with the existing product is not important, the replacement part seeks to avoid IP infringement.

Figure 3.a. Enhanced replacement cap with citrus juicer. Source: Author.

Figure 3.b. Citrus juicer cap in use. Source: Author.

Improving parts: Panasonic bread maker

The second example is an improvement to solve the problem of failure of the original part. The replacement is an internal dispenser latch for a Panasonic SD257 bread maker (Figure 4).

The part is available for sale through Shapeways. The designer claims the replacement part is superior to the original due to stronger material (stainless steel) and improved design. The designer, a long-term Computer Aided Design (CAD) user and engineer describes this process:

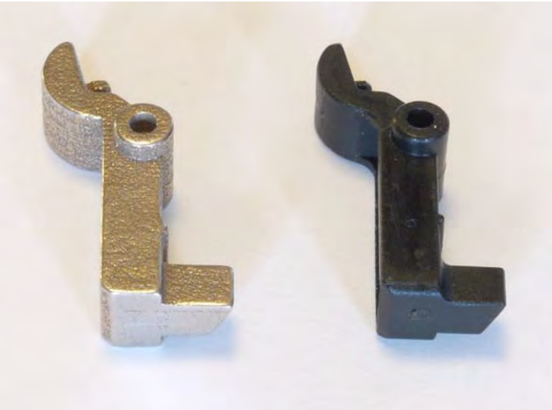

Figure 4. Panasonic SD257 bread maker original and improved latch. Source: Susan Parker.

> *"Whilst I measured the old part for general size and features, my own implementation is a from-scratch design. It is also not desirable to make a direct copy since stainless-steel printing tolerances and feature parameters have to be taken into account. The overall shape is similar, as it has to perform the same job and fit as a replacement."* (S. Parker) (personal communication, 19 January 2015),

Elements of this design needed to remain similar to the original to ensure a correct fit, while other elements were changed to suit the 3D printing process and reduce part costs. Printing in stainless steel creates superior part strength to the original, thus solving the problem of the original failure. In relation to potential IP infringement, the designer felt she was

> *"replacing a small part from a high volume brand that is not available to buy from the manufacturer. I would view it the same as a third party replacement part which can be as found for example in the automotive market"* (S. Parker) (personal communication, 19 January 2015).

Unavailable parts: loudspeaker bracket.

The third example is a loudspeaker stand bracket. The original part failed due to poor design. The strength of the bracket was compromised by stress fracture where there was insufficient reinforcement and material (Figure 5). Spare brackets were unavailable and the part was replicated in CAD based upon the original design but strengthened with longer side gussets, dispersing stress in the bracket.

Figure 4. Original part showing failure and improved design. Source: Author

Figure 5. Replacement loudspeaker bracket. Source: Oya Demirbilek.

Findings

A motivating factor for printing replacement parts is scarcity. Original equipment manufacturer (OEM) parts are hard to obtain as well as cannibalized second-hand spare parts. This is particularly relevant to prolonging the lifespans of older and obsolete products where a manufacturer no longer offers after sales support. A product may become obsolete or it may become orphaned where a distributor or parts support no longer exists. American entertainer Jay Leno built a reputation for 3D printing spare parts for his extensive vintage car collection (Koten 3013). Correspondingly for older products, IP infringement is less likely to occur as Registered Design cease after a finite amount of time. In Australia this period is five years, to reapply up to a maximum of ten years (Designs Act, 2003). The EU offer Registered Design protection in five year chunks, up to a total of twenty-five years, and the US offer four year chunks, up to a maximum of fourteen years (L. Miller) personal communication, 20 February 2015).

To reproduce a part, a designer must embark on reverse engineering, capturing the precise geometry of a part, reproducing it as a 3D CAD

file, and then optimising it for printing. During this latter stage of the design process, the designer has an opportunity to improve the part. This is clearly evident with the examples presented above. In each instance, parts have been enhanced to address the failure of the original part.

Personal desktop printers are more suited to reproducing internal or hidden parts where material colour and finish is less important and ABS and PLA plastics may not meet the engineering performance specifications needed for critical components. It would be unwise to recreate critical parts where failure could cause injury or compromise safety. Product liability and warranty is another potential issue. In such circumstances who would be responsible for the failure? Table 2 summarises the desirable circumstances for 3D printing a replacement part.

Print to repair Opportunities	**Description**
Non-availability of parts	OEM parts are unavailable from manufacturer or supplier and are rare on secondary markets.
Improve part design	• Improved durability and performance thereby addressing the cause for product failure in the first instance. • Optimised for the 3D printing process.
Hidden parts	For replacement parts where material, colour and texture matching are less important.
Non-critical parts	Replacement parts for non-critical components that do not affect product safety.
IP infringement unlikely.	May apply when: • IP rights may have expired. • The part is judged substantially different from the original. • The recreated part is a variation of a generic component like a modified bolt, screw or clip. • Exemption clauses exist within legislation allowing the reproduction of a component within a complex protected product e.g. non-OEM car spare parts. • There is authorisation to copy and share via creative commons or other licencing agreement.

Table 2. Circumstances for 3D printing replacement part.

Conclusion

There exists much excitement about 3D printing and the transformative possibilities it brings to how products are designed, manufactured, distributed and sold. Printing replacement parts demonstrates a step towards this transformation. Personal low cost desktop machines can produce functional replacements quickly and efficiently.

Online service bureaus and file sharing platforms offer a market place for makers to share, remix and trade replacement parts but technological and legal obstacles still need to be surmounted before the opportunities for printing spare parts accelerates. The technology will improve and will become more affordable, IP law will catch up, consumer perceptions and practices around obtaining parts will change and new business models will emerge with the next wave of digital technologies. When a product fails and certain replacement parts are unavailable or scarce, 3D printing offers a means for a quick and efficient repair. While the technology may herald a profusion of new and unnecessary products, it equally can be harnessed to prolong the lifespan of products that would otherwise become obsolete.

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Understanding consumer influences on product lifetimes: the Individual-Practice Framework

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Keywords: collaborative consumption; social practice theory; social psychology; values.

Abstract: In the field of sustainability, understanding consumer influences on product lifetimes is deemed essential to reduce the environmental impact of consumption. The aim of the research project which informs this paper was to investigate different ways of thinking about how consumers' values may contribute to the acceptance, adoption and diffusion of collaborative consumption – an economic model based on sharing, lending, swapping, gifting, bartering, or renting products and services enabled by network technologies and peer communities (*cf*. Botsman and Rogers, 2011). By making it possible to obtain use of goods without owning them, these alternative patterns of consumption have some potential to prevent new purchases, intensify product usage and promote reuse of possessions that are no longer wanted, thus contributing to longer product lifetimes.

The relationship between values and the participation in collaborative consumption was explored through mixed methods research drawing from two different, if not contrasting, theoretical perspectives to understand consumer behaviour: social psychology and social practice theory. Drawing on their possible complementarity, the investigation was structured in two subsequent and interactive phases: a quantitative data collection and analysis, followed by a qualitative strand of research. The initial quantitative study measured individual values through use of Schwartz's PVQ-R3 tool. Results were followed up through semi-structured interviews facilitated by a series of visual prompts. This paper presents the resulting Individual-Practice Framework, which uniquely combines insights from social psychology and social practice theory to examine and explain the interrelation between the individual, his/her personal values, and specific combinations of the 'material', 'meaning' and 'competence' elements that sustain social practices.

Introduction

Current patterns of production and consumption are widely recognised as unsustainable (*cf*. Cooper, 2005; Tukker et al., 2006). In the last two decades the idea of decoupling economic growth from environmental pressure has received growing attention from scholars, businesses and governments (von Weizsäcker et al., 1998; Jackson, 2009). Different initiatives, strategies and approaches have been elaborated in the effort to support the shift toward a resource-efficient, low-carbon economy to achieve sustainable development (European Commission, 2011). Product longevity (through longer lasting products, product life-extension, lifetime optimisation, more intensive use of goods and systems) and moving from products to services have been considered viable (design) solutions to reduce the impact of consumption (*cf*. Cooper, 2010; Stahel, 1994; Tukker and Tischner, 2006).

The rise of collaborative consumption (also referred to as the 'collaborative economy', or the 'sharing economy') – traditional sharing, bartering, lending, trading, renting, gifting and swapping, redefined through technology and peer communities (Botsman and Rogers, 2011, p. xv) – has recently attracted interest for its potential to resource-saving and waste minimisation. By making it possible to obtain use of goods without owning them, these alternative patterns of consumption can contribute to avoid new purchases, increase or extend the usable life of products, intensify product usage and promote reuse of possessions that are no longer wanted

(Leissman et al., 2013). Examples of services that foster access rather than private ownership are car and bike sharing schemes, peer-to-peer (P2P) ridesharing (e.g. Uber), P2P lodging (e.g. Airbnb) and goods/skills exchange or transaction sites (e.g. Freecycle).

Collaborative consumption, named one of Time Magazine's 10 ideas that will change the world (2011), could reframe the unsustainable nature of the present economic development path if brought into the mainstream. However, the success of this emerging socio-economic paradigm largely depends on consumers' response to the introduction of innovative, share-based (business) models in the market. Therefore, understanding (and changing) consumer behaviour is key to support the thriving of collaborative consumption.

Understanding consumer behaviour

Theories and models of behaviour and behaviour change originate from all disciplines of the social sciences, particularly social psychology and sociology (for an overview see Darnton, 2008; Jackson, 2005; Morris et al., 2012). These two conceptualise and define behaviour differently. Social psychology focuses on the individual and hold behaviour to be an outcome of a number of antecedents and determinants including personal beliefs, values and attitudes. On the contrary, sociology (mostly social practice theory) tends to aim attention at the relationships between behaviour, people and the social and physical environments in which they take place (Morris et al., 2012).

Values in social psychology

In identifying the drivers of pro-environmental and/or pro-social consumer behaviour, moral and normative considerations are often taken into account (Jackson, 2005). Some examples are Schwartz's 'Norm-Activation Theory' (1977) and Stern et al.'s 'Value-Belief-Norm Theory' (1999). The former describes moral behaviours as the result of a personal norm to act in a particular way activated by the awareness of the consequences of one's actions and the ascription of personal responsibility for them. The latter models the causal chain of influence from certain people's values and beliefs to the emergence of a personal norm to act in a given way, thus providing insights into the value basis of pro-environmental behaviour.

In social psychological accounts, values are generally defined as "trans-situational goals, varying in importance, that serve as guiding principles in the life of a person or group" (Schwartz et al., 2012, p. 664). In a major program of theoretical and empirical research, Schwartz and his colleagues have identified 19 basic individual values, organised in a circular motivational continuum according to their compatibility or conflict. These are further divided into four distinct clusters: 'openness to change' vs. 'conservation', and 'self-enhancement' vs. 'self-transcendence' values (Figure 1).

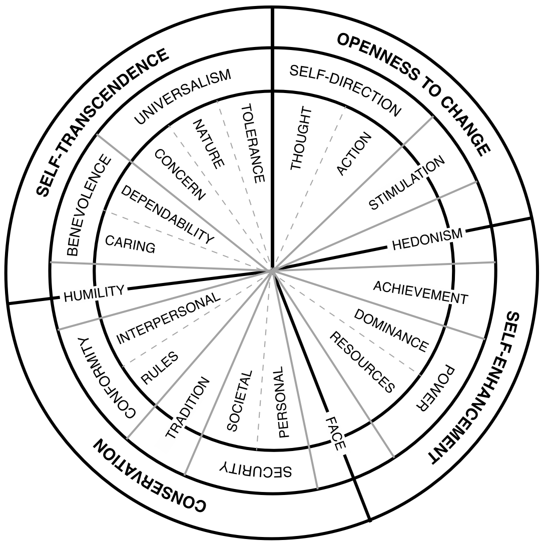

Figure 1. Circular motivational continuum of 19 basic individual values. Adapted from Schwartz et al., 2012, p. 669.

Studies suggest that self-transcendence values (in particular 'universalism') are generally predictive of positive engagement with social and environmental issues (*cf.* Gutierrez Karp, 1996; Stern and Dietz, 1994). However, their predictive power is generally low (Pepper et al., 2009). Often values do not translate linearly into action (i.e. the so-called 'value-action gap') (*cf.* Blake, 1999) and have only a weak influence upon behaviour, usually mediated through other variables.

'*Meaning', 'Competence' and 'Material' elements in social practice theory*

In recent years social practice theory has attracted growing attention as an alternative approach to understanding consumer behaviour, which places social practices rather than individuals at the centre stage of analysis. 'Practices' that make up everyday life – showering, cooking, driving, doing the laundry – are understood as social phenomena whose 'performance' entails the reproduction of cultural meanings and tastes, socially shared knowledge and skills, and material artefacts (Spurling et al., 2013). These elements were grouped by Shove et al. (2012) under the three categories of 'Meaning', 'Competence' and 'Material' (Figure 2).

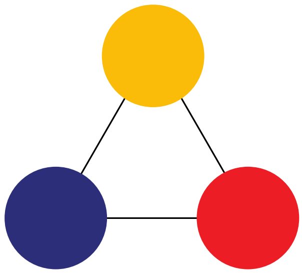

Figure 2. Elements of practice. Adapted from Shove et al., 2012.

Resources are consumed in the reproduction of social practices and what people take to be 'normal' and ordinary ways of doing and living (Shove, 2003). Therefore, the focus moves from determining the antecedents of individual behaviour (e.g. values, beliefs and attitudes) to appreciating the collective dynamics of the routinisation of practices and their underlying shared notions of normality.

However, it is possible to question the degree to which culturally and socially constructed conceptions of normality play out through personal actions in practices. The extent to which common understandings, norms, social expectations and conventions (i.e. the 'meaning' element of practice) may be mediated by and through personal traits and characteristics, including individual values, is under investigated (Piscicelli et al., 2015).

Methodology

Drawing on the possible complementarity between social psychology and social practice theory (*cf.* Darnton et al., 2011; Whitmarsh et al., 2011; Wilson and Chatterton, 2011; Boldero and Binder, 2013), the research project which informs this paper examined the role of values in the context of collaborative consumption. Ecomodo, a UK-based P2P online marketplace for lending and borrowing, was used as a case study.

Mixed methods research was conducted in two subsequent phases. Initial quantitative data collection and analysis measured the value priority of 63 Ecomodo users through Schwartz's PVQ-R3 tool (*cf.* Piscicelli et al., 2015). In the qualitative strand of research, results were followed up through 10 semi-structured interviews which explored whether and how individual values may act upon the 'meaning' element of practices contributing to (or hindering) the acceptance, adoption and diffusion of collaborative consumption.

Results and discussion

As part of the interview, a series of prompts and scenarios were used to uncover values associated with alternative ways of consuming in the context of transportation, holiday accommodation, clothing and consumer goods. In this paper, the relationship between individual values and meanings is discussed using results from the area of clothing.

Interviewees were invited to associate relevant Schwartz's values (Figure 1) to buying a new item of clothing in a shop; looking online and hiring a designer brand garment for few days through Girlmeetsdress.com; swapping an item of clothing they own for another one with somebody online or at a swapping party. Values most directly associated to these alternatives were: 'Hedonism', 'Face', 'Achievement', 'Universalism-nature', 'Stimulation' and 'Self-direction-action'. Associations made proved to be either positive or negative, in the light of the meanings taken into consideration for each option.

(Socially shared) meanings

Clothing was generally related to ideas of wastefulness and inefficiency. Accordingly, buying new clothes was negatively associated with 'Universalism-nature', which was positively linked to hiring and swapping solutions. This seems to suggest that meanings underlying practices are not necessarily socially shared. Whereas interviewees primarily viewed clothing as environmentally unsustainable, mainstream

understandings may differ. Personal endorsement of a certain set of values is likely to affect what meanings are seen as relevant in each practice.
Furthermore, individual value priorities may influence the direction of the association (i.e. positive or negative). Clothing was related to ideas of self-gratification. However, ‘Hedonism’ and ‘Stimulation’ were associated negatively with buying new clothes and positively with hiring and swapping solutions where the pleasure and “*thrill*” of getting something new occur “*without the guilt*”. This could be explained by interviewees’ view of fashion as unsustainable and the higher importance they attribute to ‘Universalism-nature’ compared to ‘Hedonism’ and ‘Stimulation’ (*cf*. Piscicelli et al., 2015).

Misaligned meanings
Values can also bring people to reject meanings that are recognised as mainstream and largely socially shared. For example, interviewees criticised the common understanding of clothing as a way to show personal success and its use as a criterion to judge others. Therefore, buying new clothes was negatively associated with ‘Face’ and ‘Achievement’, values that they hold of low importance.

A misalignment between endorsed values and meanings can lead people to either engage in alternative practices (e.g. buying second hand clothes rather than new), or find ways to deal with the perceived inconsistency (e.g. buying new, but organic clothes).

Conclusion
The analysis uncovered the values that Ecomodo users associated with different alternatives (i.e. buying new, hiring, and swapping) in the area of clothing. Findings revealed the existing relationship between individual values and social meanings. In particular, they demonstrate how meanings are culturally constructed and socially shared, but individually renegotiated.

This explains the possible difference in the meanings that people associate to a certain practice (e.g. someone may see buying new clothes as unnecessary and wasteful, whereas others may find it an enjoyable activity and a way to keep up with fashion). Furthermore, this suggests a potential link between meanings and motivations for action, thus demonstrating the need to address more explicitly the role of individual agency in the context of practices and social practice theory.
Departing from Shove et al.’s model (2012) (Figure 2), the resulting Individual-Practice Framework (Figure 3) positions the individual at the centre of the practice itself. In doing so, it overcomes the ‘agency-structure’ divide by acknowledging the existing interaction between the individual and a particular configuration of ‘material’, ‘competence’ and ‘meaning’ elements.

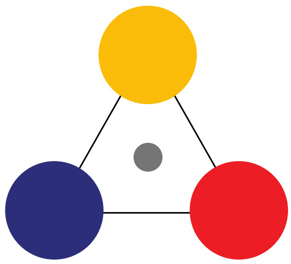

Figure 3. The individual-practice f2ramework. Piscicelli et al., 2015.

Besides connecting the elements together through the reproduction of a practice, the individual interacts with, and renegotiates, each element. This relationship is mediated by personal preferences and characteristics, such as individual values.

To conclude, the Individual-Practice Framework uses and extends approaches from social practice theory by complementing them with insights from social psychology. In doing so, it offers an alternative perspective to understand behaviour and practices which is particularly well-suited to explain consumer influences on the acceptance, adoption and diffusion of more sustainable patterns of consumption.

Acknowledgments
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Uncertainty modelling for extended product lifecycles: application of a biological analogy to product lifecycle management

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Keywords: adaptive landscapes; product lifecycles; product geometry.

Abstract: Product lifecycles are determined at a point in the planning process where there is great uncertainty in future market conditions and drivers for change. Particularly for products with high investment costs and long lifecycles, the period of production may be considerably longer than the change cycle for new technical developments, legislation changes, market conditions, etc.

Using internal combustion (IC) engines as an exemplar of products with long planned lifecycles (10-20 years) and heavy investments (~£200M), a model has been developed to help predict probable, but uncertain, geometry changes in product architecture over expected lifecycles. The model draws on a biological analogy to apply adaptive landscapes to product architecture choices, building in robustness to requirements variation over the life of the product.

The model has been applied to historical examples of the evolution of a family of products from first introduction, through to end of production. In this way, actual lifecycle extension, modification and change can be compared to modelled approaches to validate heuristic values to be used in future product planning.

The use of adaptive landscapes allows products to be defined in such a way that they are more robust to ill-defined, but reasonably expected changes in product configurations and requirements. Thus, reducing total lifecycle investment costs and allowing products to be more responsive to changed circumstances. Through this process, the lifecycle of products can be extended for minimized cost of change.

Introduction

> *'It is not the strongest of the species that survives, nor the most intelligent; it is the one that is most adaptable to change'*
>
> Charles Darwin

New products are developed to satisfy defined customer needs, working within the constraints of known expectations over the life of the product manufacturing period. Taking the product lifecycle to mean the period over which a product is conceived, developed, launched to market and is in production, the end of life is therefore determined when a product line ceases to be manufactured.

The word lifecycle implies a biological analogy to the life history of an individual biological entity – its development over time and the evolution of its form throughout its many changes (Stearns 2004). This approach can be applied to species development, as the general physical arrangement of an entity evolves, driven by dominating environmental conditions (McGhee 2007). The physical configuration of a species is therefore more or less fit in relation to the environment in which it exists (Dieckmann et al 2011).

Darwinian natural selection is now well established as the driving mechanism for development in nature (Weibel 1998). The essential elements of evolutionary theory being variation, selection and inheritance. The selection process in biology working on the basis of the concept of 'fitness'.

Fitness can be seen as a dynamic, optimizing process. Flora and fauna that have greater degrees of fitness for attributes that enable survival and reproduction, are more likely to pass on their genetic materials to future generations. In recent decades, this concept has been applied to a number of fields outside biology, such as economics (Dosi & Nelson 1994), social behaviours (Godfrey-Smith 2012), business operation (Piepenbrock 2009) and engineering (Whitacre 2012).

Technological products can be thought of as evolving under the pressure of environmental constraints, in the same manner as biological entities (Brasalla 1988). Techniques to apply evolutionary methods to design and engineering have led to such methods as genetic algorithms, biomimicry and other methodologies that apply a biological analogy to optimization in design (Businaro 1983, Bentley 1998, Schatten & Zugaj 2011).

As the quote from Darwin at the start of this paper suggests, fitness in a biological environment refers most often to a collection of attributes that are *good enough* to ensure survival, rather than optimal in any mathematical sense.

One of the challenges of designing engineered products is to ensure that they are robust to uncertain future conditions. The science of engineering and the discipline of design is dominated by optimization. Products are developed to meet known requirements in as optimal a way as possible, against multiple criteria. Known variations in conditions and requirements are catered for by ensuring robustness to defined degrees of variation, often through the use of modular design or planned capacity in the design for adaption to variation at a later date. The challenge arises when possible future changes to product geometry is expected, but uncertain.

Under these circumstances a price will be paid for building excess capacity for adaption at a future date, in the form of product geometry that is sub-optimal for size, weight or other key product characteristics. The product designer must therefore balance the need to launch a product to market that suits the immediate needs of the marketplace, whilst having capacity for extended life built in to minimize the costs of change at a later date.

Methods: modelling and simulation

Adaptive Landscapes

The concept of adaptive landscapes (AL) was first proposed by Sewall Wright in two short papers in 1931 and 1932 and later expanded in a more complete coverage in later years (Wright 1969;Wright 1988). Wright proposed a ‘landscape’ where the ‘terrain’ of that landscape is generated by the fitness function resulting from the interaction of the functions of two biological attributes. The adaptive landscape theory has a long history adoption and although less than perfect as an analogy, it nonetheless has proven useful in modelling evolutionary pressures on driving speciation and change (Ruse 1990).

Higher peaks on the landscape would indicate higher fitness – a desirable position to achieve to ensure survival. Valleys and low lands on the landscape would indicate sub-optimal combinations of features and attributes, best avoided to ensure a longer life.

The flora or fauna under consideration would have a number of combinations of attribute, each with a corresponding landscape. The value of defining these landscapes are three fold:

1. Visualization – Landscapes allow a clearer visualization location and of range of fitness peaks

2. Optimization – Relative fitness peak heights define optimal solution locations, enabling ‘peak jumping’ for global solutions rather than local optima

3. Sensitivity – The slope of the fitness landscape at any point indicates the sensitivity to change when moving away from a current location.

As attributes change, they move across the landscape surface finding a place higher or lower on the fitness surface. Darwinian evolution tells us that those attributes that find themselves at higher elevations are more likely to survive.

Product Adaptive Landscapes

Applying adaptive landscapes to product designs, key attributes can be modelled to better understand the interaction of features and find optimal configurations.

When applied to product design, adaptive landscapes have been used successfully to uncover optimal peak points.

Within a design space, locations on the landscape may fail to meet essential levels of performance. Searching the landscape in these regions is unproductive and is to be avoided. By ‘flooding’ the landscape to a depth equivalent to the contour level associated with infeasible attribute combinations, a clear cut-off to the design search space is established. Any attribute combination above the flooded plane is therefore feasible and an acceptable solution. The remaining landscape above the flooded plane can then be searched for optimal peaks. This landscape can be referred to as a flooded adaptive landscape (FAL).

Product attributes defined by the adaptive landscape can be thought of as key physical geometry that determines functional characteristics of the product and therefore its ability to ‘survive’ in the marketplace. Considering Darwin’s definition of fitness being related to adaptability to change, a relatively flat optimal peak would allow adjustments in attribute values i.e. changes in geometry, with little change in optimization.

Considering the optimal peaks as an adequate ‘truncated plateau’ to the landscape, allows the designer to put adaptability into the right context for making product configurations robust to change. This modified peak adaptive landscape can be referred to as a truncated adaptive landscape (TAL). Combining both flooding and truncation generates a truncated, flooded adaptive landscape (TFAL), that defines a zone of robust adaption (the truncated plateau, a zone of feasible, but sub-optimal solutions (the landscape slopes) and a zone of infeasible or otherwise undesirable solutions (the flooded plane).

Figure 1 shows a product design adaptive for representative attributes ‘A’ (At_y) and attribute ‘B’ (At_x). The fitness function (Ft_z) is defined by the landscape peaks.

The truncated, flooded adaptive landscape therefore generates a ‘slice’ of landscape that is feasible for exploration.

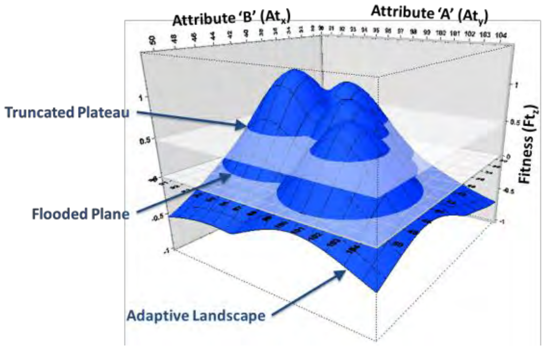


Figure 1. Product Adaptive Landscape.

Internal Combustion Engine Feature Modelling

Internal combustion (IC) engines are capital intensive products, with a long product production lifecycle. Over the production life of an engine, many changes in geometry may be necessary to cope with changing requirements to meet new standards, customer feature and performance expectations and to respond to market drivers, such as new competition.

Investigations into the investments required into engine production facilities and tooling show costs in the £80-250m range for automotive applications. The tooling and equipment for large scale engine production is usually dedicated to the production of fixed product geometry. Building in flexibility adds considerable cost (15-30% additional cost) which manufacturers are reluctant spend if there is not a good rationale justifying the expenditure. This flexibility is to adapt the product to often ill-defined changes 5-10 years after production has started, 8-12 years after the geometry for the product may first have been defined during the concept design stage of the products life.

Truncated, flooded adaptive landscapes allow the designer to understand the sensitivity to geometry change, whilst considering feasible solutions. By defining TFAL landscapes for key geometric attributes of engine designs, degrees of uncertain, but reasonably expected geometry change can be considered.

As the exact geometry changes that may be required at some distant point in time are unknown, a probabilistic approach to assessing the requirements is used.

Figure 2 shows the design process developed. Heuristics derived from similar prior engine life histories are generated. These are used to moderate the requirements for the new product, generating a set of inputs into a multi-criteria decision making process. The outcome of this initial optimization stage is to define an adaptive landscape - a design space within which further optimization can occur.

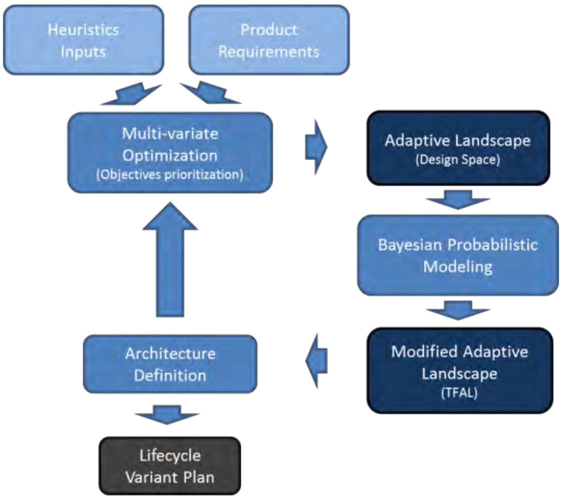


Figure 2. Adaptive Landscape Design Process.

Applying a probabilistic approach to expected changes and its sensitivity to adaption, a modified truncated, flooded adaptive landscape is produced (TFAL).

The TFAL solution space is used to select appropriately robust geometry to move forward into embodiment design.

The robustness of the TFAL model defines what variants in product geometry are possible without additional capital equipment and tooling changes (on the truncated plateau) and which are feasible, but may require further investment (on the landscape slopes). It also clearly defines infeasible solution sets (the flooded plane) that would require a new engine program or major reinvestments to satisfy.

Application of the TFAL Model

The application of the TFAL model can be seen in Figure 3. Here an adaptive landscape has been generated based on benchmarking data of existing engine designs and provisional analysis of feasible zones based on known geometry limitations and manufacturing constraints. Input data from competitor benchmarking, current product offerings and concept analysis is usually sparse. A 3D surface for the adaptive landscape is generated from a point set which may only consist of 5-8 data points. The validity of this surface is checked against known feasible solutions using datasets with 200-300 data points from benchmark data.

A Bayesian probabilistic model, utilizing historical heuristic data on likely geometry changes over the expected production lifecycle is used to generate a flooded plane and truncated peak.

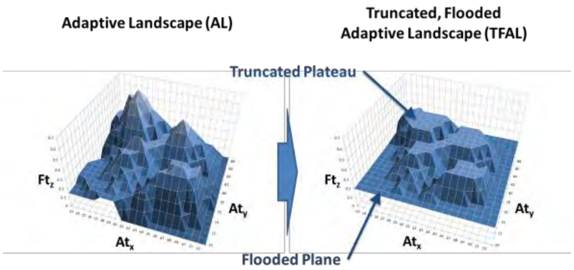


Figure 3. TFAL Landscape Generation.

The resulting TFAL landscape is used to explore geometry selection options, with an emphasis on a design configuration that will be robust under conditions of uncertainty, rather than finding a theoretically optimal design against current conditions.

Pareto Frontiers

The landscape truncated peaks generated may be a single surface, or several dispersed surfaces that represent optional equally optimal peaks.

Attributes may interact in such a fashion that a Pareto frontier defines an optimal edge to the design space. Figure 4 shows a 3D adaptive landscape of the Pareto frontier edge. Outside of the frontier, fitness values drop off markedly to an infeasible zone. Behind the Pareto frontier lies a feasible plane, with gradually diminishing optimality as solution sets move away from the frontier.

Figure 5 shows a 2D representation of the Pareto frontier where all solutions along the frontier are considered equally good.

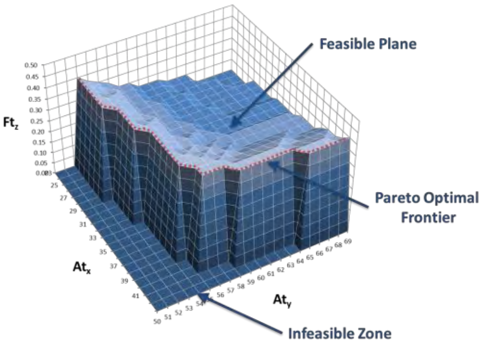


Figure 4. 3D Pareto Frontier.

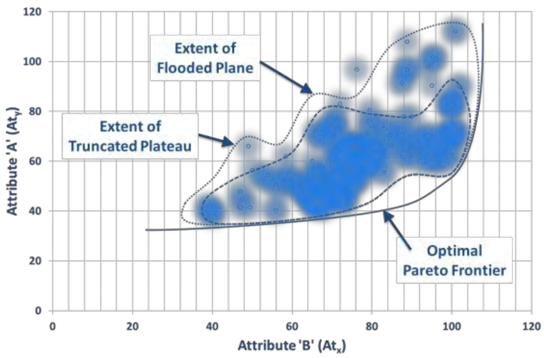


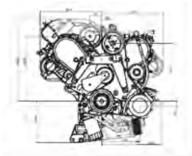
Figure 5. 2D Pareto Frontier.

Superimposed on the map of the frontier are the extent of the truncated plateau and the flooded plane. Using a 2D representation of the TFAL surface is more useful in enabling the designer to move from a visualization tool into using the TFAL surface to select appropriate values for consideration in the design configuration.

Conclusions

Product lifecycle changes can have profound effects on the economics of a business (Spitzley, Kim & Keoleian 2005). The TFAL design approach was applied to some historical engine life histories to validate the approach and estimate the potential impacts it could have on financial and environmental performance.

Several engines with well documented development histories were chosen to retrospectively apply the TFAL process. One example is the Rover K Series engine which was originally developed as an inline four cylinder engine of 1.1l and 1.4l displacement. Due to unexpected changing requirements over the production life of the engine, it was eventually produced in six displacements across inline and vee configurations, as a 4 & 6 cylinder engine. Further developments included turbo-charged and Diesel variants (Hammill 2010).



	L4				V6	
	1.1	1.4	1.6	1.8	2.0	2.5
	2V/4V	2V/4V	4V	4V/VVC/Turbo	4V	4V
Bore (mm)	75	75	80	80	80	80
Stroke (mm)	63	79	79	89.3	82.8	66.8
Bore Bridge (mm)	13	13	8	8	-	-
Bore Centers (mm)	88	88	88	88	-	-
Weight (kg)	85	85	90	90	145	145
BHP	60/75	75/103	116	120/160	150	190
	Original Design					

Table 1. Rover K Series Engine Geometry.

The original design of the Rover engine was optimized for low weight and compact size, driven by a need for fuel economy and efficiency. The geometry changes of bore/stroke and configuration meant that many of the primary enablers of the early design features, such as through bolting and low-pressure die castings, needed significant additional reinvestment to continue to be used.

A consideration of past developments of similar engines and scenario planning for probable but uncertain future features demands through adaption of TFAL would have avoided nearly 70% of the subsequent additional investment to extend the production life of the engine family.

Similar validation activities were done using engine production life histories of the Chrysler 2.5l four cylinder engine (Weertman 2007), the BMW GS Boxer engine (Schneider & Koenigsbeck 2009), BMW K Series (Walker & Dobson 1989) and the Coventry Climax racing engine (Hammill 2004, Robson 1975).

These engines were chosen as they have long production lifecycles, have undergone significant architectural configuration development post production launch and have been produced in high volume, therefore meeting the criteria for application of the TFAL methodology.

Adaptive landscapes were developed from an analysis of sensitivity to change in key geometry architecture, such as bore/stroke ratio, cylinder block height and camshaft centres. Truncated, flooded adaptive landscapes were derived to bound the limits of adaptability within the constraints of manufacturing equipment fixed geometry. Heuristics were drawn from these historical examples that can be applied to future engine configuration work.

Production end of life for engines is most usually arrived at when geometry changes required due to the needs of engine evolution obsolete existing manufacturing equipment.

Table 2 indicates the cost of building adaption capability into a product design, using the TFAL method. Initial costs are 15% higher and the product may be marginally sub-optimal compared to competitive products on the market for size, weight, etc.

Building in robustness to IC engine geometry using the TFAL modelling method, will extend the life of the engine in production. It is estimated that on a typical engine project, 3-8 year of extra production life could be added by building in adaptive capacity. The average automotive engine production life before major change is 5.5 years. Application of TFAL therefore has the potential to extend production life by 50-140%.

The main driver for geometry change in IC engines is a need to comply with emissions regulation introduction. Emissions legislation is typically applied on 3-5 year cycles, which means that a new engine design will need capacity to cope with an expected 2-4 major changes in emissions requirements over its production life.

Changes to legislation and market conditions are thus expected, but not fully defined or known at the point of concept design.

	Engine 'A'	Engine 'B'
Initial Investment	100%	115%
Change Cost	75%	20%
Product life expected	10 years	10 years
Product life actual	6 years	12 years

Table 2. Adaption costs.

Building robustness into the design allows for these changes to be adopted with minimal re-investment. Extending the production life of the engine in production reduces waste through greater utilization of investments already made. The cost of change is minimized by building in robustness to change, therefore using resources more efficiently.

A more robust approach to product geometry definition therefore brings environmental benefits in terms of better use of resources as well as faster adoption of product to meet new environmental standards.

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Critical end of life analysis: managing the downside of the lifecycle

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Keywords: end of life; product lifecycle.

Abstract: Planning for product lifecycles contains many unknowns and uncertain projections of future conditions. The further into the future that planning is projected, the more uncertain or subject to change are the factors that determine product life such as market conditions, product performance in the field, economic environment, dominant legislation, competition, etc.

Through a series of detailed interviews with product developers and analysis of real-world product lifecycles, a picture emerges of the degree of uncertainty around predicting product production life. Comparisons of planned versus actual product cycle (point of introduction, production/sales volumes, rise and decay rates, end of life), provides insights into the relative impact each stage has on return on investment and decisions concerning whether a product should be removed from the market.

A sensitivity analysis has been conducted to provide a view on the criticality of end of life decisions on overall product lifecycle success. Consideration is given to premature termination of life, decisions on life extension through modification, adaptation and upgrade, as well as the implications of unmanaged terminal decline.

The consequences on passive management of end of life are considered, with the broader consequences this may have on follow-on products, service support and resource utilization. The findings indicate that end of life planning is generally poorly done and inadequately managed. This has a significant impact on product commercial success, potentially greater than introducing the wrong product to market or not achieving desired sales volumes.

Product lifecycles

The product lifecycle is that period of time covered by the introduction or acquisition, use and eventual disposal of a product – analogous to the lifecycle of a biological entity (Day 1981). It is often taken to mean the lifecycle of an individual product, used by a consumer; the life of an individual assembly of components in a functional role (Businaro 1983).

This study considers the lifecycle of a ‘species’ of products, a product family from the development of the product and its introduction to the market, through its many related variants, upgrades and derivatives over time, to the point where the product range is removed from production.

The definition of a distinct product ‘species’ for this study relies on a natural relationship of physical geometry features and characteristics within a ‘family’ of product offerings.

Lifecycle stages

The product lifecycle stages are indicated in Figure 1. An initial investment is made in engineering and product development. This includes costs for tooling, production set-up, marketing launch, etc.

Once launched the product will generate revenue and is expected to breakeven and move into profitability within a time planned in the business case for the product.

Following a typical Bass market penetration curve (Bass 1969), product sales will eventually reach a turnover point, at which, due to the effects of competition, product aging and market saturation, sales will decline and the product will be removed from sale.

The product lifecycle curve has four distinct stages:

1. Development and introduction
2. Launch to breakeven
3. Profitable production life
4. Decline and termination.

This final stage, when sales are stagnant and returns on investment are relatively poor, is referred to as end of life (EoL).

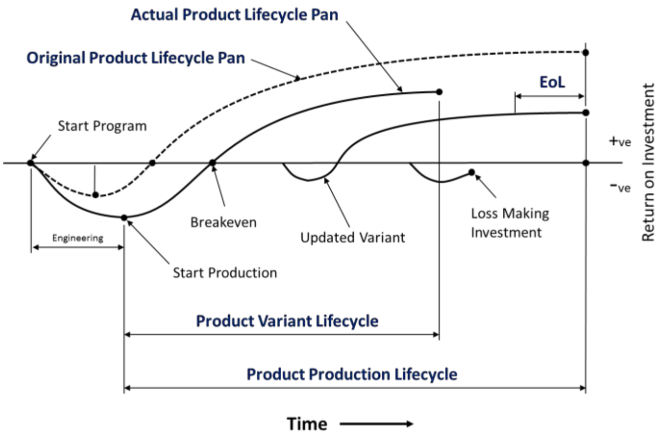

Figure 1. Lifecycle revenue.

The illustration of product lifecycle (Figure 1) indicates a planned lifecycle for the product, used for business case justification and on known data at the time of planning. Actual lifecycles will be different as a result of market acceptance of the product, the quality of project execution and the responses of competitors, amongst a host of other factors (Klepper 1996).

An individual variant of the product can be mapped as a lifecycle, as well as the combined lifecycle of related variants, upgrades and derivatives that emerge over time – see Figure 1 above. This study considers the product production lifecycle to include all related variants of a product family up to the point of obsolescence i.e. the product family as an identifiable 'species' defined by its geometry, is no longer in production.

Methods

Information on a representative range of new internal combustion (IC) engines programs (NEP) was gathered through surveys and interviews of industry practitioners.

This data was analysed to draw out representative heuristics for modelling the stages of product production lifecycle.

Surveys and Interviews

A survey of product developers in the IC engines industry was conducted to gain insights into experience with planning and executing full engine programs. Potential respondents to the survey (n=103) were identified from a database of professional engineers and other key stakeholders in new product development (NPD), built up from consulting contacts, industry network forums and prior work colleagues of the author. In all cases, the potential respondents were known NPD professionals in industry with >5 years' experience in the IC engines industry. Response rate to the survey was high at 53%.

A selection of survey respondents (n=19) with the most relevant experience of new engines programs, were selected for follow up interviews. Interviewees were from a number of sub-disciplines: Designers (n=9), project managers (n=6) and marketing professionals (n=4).

Interviewees were globally dispersed, located in Asia (n=3), Europe (n=7) and the Americas (n=9). Both engineering consulting companies (n=10) and engine manufacturers (n=9) were represented in the interviewee group.

The combined relevant new engine program experiences of the engines NPD professional consisted of 84 projects covering a period of nearly 30 years, the majority completed in the last 15 years.

Average experience of the interview cohort was 16.1 years (SD=6.03, Max. 30, Min 6). No significant difference was noted in responses based on location, role or type of business.

Interviews were conducted to gather data on new engine programs (NEP) experiences of the interviewees. The definition of a NEP for the purposes of this study was taken as an engine design project that was substantively 'new' from previous products in the company portfolio, with major changes to geometry and layout e.g. different engine bore/stroke, displacement, number of cylinders, etc. NEP engines were not derivatives or variants of existing engines, but a new 'family' of engine for the business, with substantially different geometry to the product they replaced.

To be included, any NEP example had to be personally experienced by the interviewee or one that they had intimate knowledge of, so that the details of product planning and delivery were internally validated and realistic.

Lifecycle modelling

Based on the responses from the NPD professional interviews, a series of modelling heuristics were developed to allow a sensitivity study of the potential impact of each stage of the NEP lifecycle to be generated. These heuristics were used to consider the role of end of life (EoL) in overall product return on investment (RoI).

Results

The results of the study were compared to published secondary data to establish comparative benchmarks that might be used for future program planning activity.

Planned vs Actual product ifecycles

The results of the combined projects considered in the study show a significant deviation from planned product production lifecycle (average 10.6 years) compared to actual time to replacement or end of life (average 5.5 years).

Table 1 shows the data from the survey, including the ranges of responses and the delta (Δ) or deviation of actual from planned.

(years)	Planned	Actual	Δ	Δ%
Max	15	12	2	20%
Min	6	2	-11	-83%
Average	10.6	5.5	-5.2	-46%
SD	2.16	2.04	3.02	23.89%

Table 1. Study product lifecycle duration.

These results compare to data obtained from secondary published sources for a range of engines product production lifecycles (Table 2). Secondary data sources used to compile these industry benchmarks are from Autodata (2013), Sankaido (1999) and Wards/Mahle (2014).

(years)	Industrial	Automotive	Motorcycle	Utility
Max	40	35	18	24
Min	5	2	1	3
Average	16.12	8.32	5.38	12.34
SD	2.9	3.04	2.87	3.02
n	132	537	234	118

Table 2. Engines industry product lifecycle durations.

The new engines programs used for Table 1 were primarily a combination of automotive and motorcycle programs. In comparison to published data in Table 2, the results are closest to motorcycle and high performance applications, which may partially be the result of the types on products considered.

The data used to generate industry lifecycles in Table 2 is drawn from a wide variety of sources responding to generic surveys. Errors in interpretation and anomalies when compared to known engines product lifecycles with the industry published data, suggest that the study survey data in Table 1 has a higher degree of internal consistency and validity, albeit taken from a smaller sample size.

Utilizing a single secondary source (Autodata 2013) to ensure better internal consistency, Figure 2 shows the product lifecycle for motorcycle models in Europe from 1987 through to 2013. These results indicate the span of individual motorcycle models utilizing a unique engine configuration. The data used are for products in the marketplace where the product has both an introduction date and market exit date for all examples i.e. no longer in production.

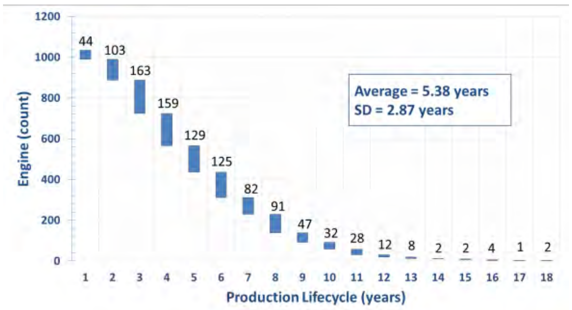

Figure 2. Motorcycle product lifecycle duration.

The size of the bars for each year indicate the number of motorcycles that had a completed lifecycle within the period indicated e.g. 44 motorcycles had a complete production cycle of only one year from introduction to termination of production. The position of the bar indicates the total number of motorcycles in production with at least one year of production e.g. 1034 motorcycle models had *at least* one year of production, of which 44 had *only* one year of production.

A family of engines may be used on more than one model, extending the lifecycle of the engine beyond that of the vehicle model. This explains why the Autodata lifecycles appear to be shorter than the study results.

Figure 3 shows the motorcycle model lifespan including products that have exited the marketplace as well as current production offerings (Autodata 2013).

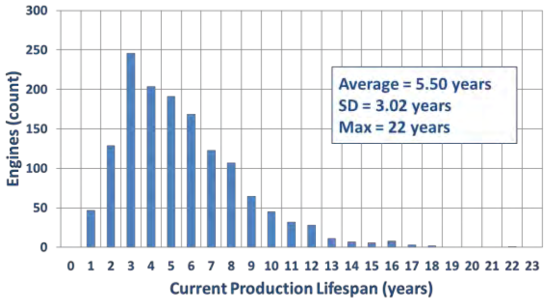

Figure 3. Motorcycle current product lifecycle Duration.

Cost impact analysis

Data on the investment costs for typical IC engines programs was obtained from secondary sources (MIRA 1997) and validated against known project performance information from study interviewees.

Benchmark data on the investment costs of sample engines project (n=9) across a range of automotive engines programs (MIRA, 1997), indicates an average cost of launch at $557m (SD=$428). Average return on investment for automotive programs is 8% (SD=4%).

Table 3 shows the impact of project overruns to cost and time for the study projects (n=84), together with impacts on time to breakeven and end of life.

	Investment Cost Overrun	Launch Time Overrun	Ramp Up Rate	Ramp Down Rate
Max	65%	50%	18%	24%
Min	-8%	0%	-20%	-58%
Average	16.7%	7.9%	1%	-15%
SD	11.70%	11.76%	5.89%	12.33%

Table 3. Motorcycle current product lifecycle duration.

It can be seen from Table 1 that there are significant deviations of planned product production life before major changes to geometry compared to actual lifecycles, with an average 46% reduction over expected time to replacement. This is a reflection of the need to respond to unanticipated legislative change, such as more stringent emissions standards, as well as reflecting higher demands from the marketplace for improved products (Daniels 1997).

Interviewees consistently expressed the view that initial planning contained significant uncertainties and that this resulted in an over confidence in the product solution having a long production life. In order to get business case approval for the high capital expenditures required, there has been a tendency to downplay the need for regular refresh of the product and to be somewhat optimistic about both sales volumes and life of the product in the marketplace.

Relatively little time is spent in quantifying end of life (EoL) of the product, as information on this end of the lifecycle is speculative and uncertain. The emphasis is on initial launch success and immediate market acceptance.

Applying the reduced product return on investment due to premature end of life, indicates a significant potential net negative impact when compared to the effects of delayed launch, reduced ramp up rate or extended time to market. This is as a result of a greater emphasis on front-end planning of projects and the greater degree of certainty of events proximate to launch.

End of life is a generally a poorly managed stage in the product lifecycle, with all interview respondents indicating a reactive culture that is generally slow to respond to changes.

A poorly managed end of life phase has the potential to eliminate the lifecycle profits of the product.

Planning of initial launch was estimated to consume the vast majority of time in planning lifecycles for new products, with end of life only being given cursory consideration by contrast.

Conclusions

The current study provides some useful benchmarks for IC engine lifecycle performance. These can be used to present a more realistic picture of the need for regular product replacement to deal with unknown, but expected changes to engine architecture. A more detailed planning activity around all phases of product lifecycle would allow better returns on investment and utilization of resources.

Product architectural geometry changes under uncertainty can be provided for by planning shorter product lifecycles, allowing for better planning of obsolescence or replacement; or by configuring capacity for likely, but ill-defined changes in product architecture at a future date. Such a strategy would allow quicker times to market for appropriate variants, extending the useful life of the product in the market and reducing waste.

Premature exit from the market, due to mis-calculated EoL results in wasted investment and negative impacts on service support provision beyond EoL.

Further work to extend the application of heuristic models to different IC engine industry applications and ultimately to other products is being currently being investigated.

A limitation of the approach is that it is most suited to products that have a combination of long production lives (>10 years), requiring high investment costs and relatively low rates of return (<10%). These types of product lifecycle are most susceptible to dynamic market conditions, competitive pressures, legislative changes and other factors that create uncertainty on product planning over an extended lifecycle period.

Products that allow a fast return on investment, have stable, known market expectations and relatively short, planned lifecycles, can achieve suitable returns on investment in expected timeframes.
This means that the proposed technique is best suited to capital intensive products with long lifespan, such as high value/volume manufacturing, infrastructure products, building and civil engineering projects, etc.

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Environmentally sustainable design practices amongst the world's largest consumer electronics manufacturers

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Keywords: sustainable design; industrial design; environmental reporting; consumer electronics.

Abstract: This research aims to determine what the world's top 12 consumer electronic product manufacturers are doing to address the adverse ecological effects arising from electronic goods flooding not only the market but also landfill sites. Corporate environmental reports were consulted for evidence of sustainable design approaches employed throughout the lifecycles of manufactured electronic products. These approaches and practices were tabulated and cross-referenced with those found in the Okala ecodesign strategy wheel developed by the Industrial Designers Society of America. The analysis shows that electronics producers do adopt a wide range of sustainable design strategies, not just to comply with regulations, but also to promote themselves as taking leadership in environmental innovation and corporate social responsibility.

Introduction

Consumer electronic products provide us with digital entertainment, information, mobile communications, and networked computing, and it's difficult to imagine life in the 21st century without them. However, rapid technological development and aggressive advertising jointly render last year's gadgets obsolescent in people's minds. The sustainability impacts and advancements of the consumer electronics industry have been widely discussed (CEA, 2008, 2010, 2013; ECMA, 2010; Greenpeace, 2012, 2014). Stringent environmental laws in the European Union – particularly the WEEE, RoHS and REACH directives – have driven many global manufacturers to improve their products and processes (EU, 2006a, 2006b, 2012, 2013).

Methodology

This paper explores the ecologically-oriented product design activities of the largest manufacturers in the consumer electronics industry. Corporate environmental and sustainability reports, and technology and environmental news on greener electronics were consulted.

'Consumer electronics' is defined in this paper as digital devices containing electronic circuit boards, intended for everyday use for personal entertainment, communications and office productivity; electronics used in the kitchen, laundry or household cleaning are excluded.

Market studies were consulted to shortlist the top 12 companies: Acer, Apple, Dell, Hewlett Packard (HP), LG, Microsoft, Nokia, Panasonic, Samsung, Sharp, Sony and Toshiba (Business Insights, 2010; Fortune, 2014).

The Okala Eco-design Strategy Wheel (White et al. 2013) was used as the basis for establishing which environmentally sustainable design approaches are used by each manufacturer. This tool was developed by the Industrial Designers Society of America, based on the Lifecycle Design Strategies (LiDS) Wheel originated by Delft University of Technology (Brezet & Van Hemel, 1997).

Results

The information gathered from the corporate reports and news was tabulated against the 47 Okala eco-design strategies and analysed (Figure 1). Due to limited space not all strategies are discussed.

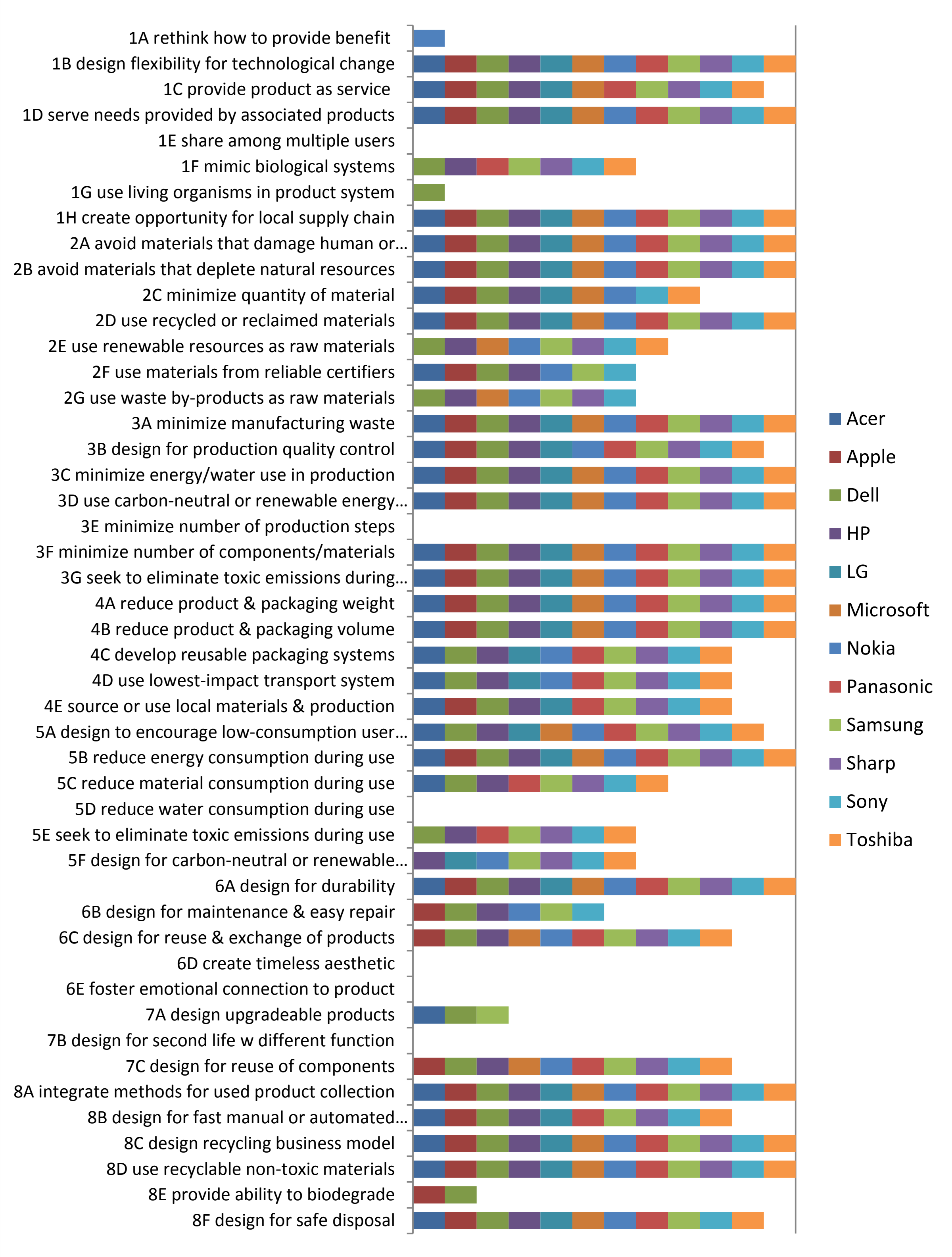

Figure 1. Okala ecodesign strategies used by consumer electronics manufacturers.

Design for innovation

Nokia's decision to not include a free charger with each new phone is an exemplar of the Okala strategy 'rethinking how to provide the benefit'. If one's old charger does not work with the new model a new charger can be separately purchased. The new box shrunk to one-fourth of the original size, and allowed Nokia to ship the same amount of products in half the number of trucks.

An example of 'providing the product as a service' is the 'software as a service' (SaaS) approach, practiced by 8 manufacturers, in which licensed software products are delivered to customers via cloud computing over the internet, thereby avoiding emissions from shipping, packaging and CD manufacture.

Only one case was found for 'using living organisms in product system': Dell's servers are protected during shipment by Ecovative mushrooms grown into foam-like cushion shapes using cotton, rice hulls or wheat chaff.

'Mimicking biological systems' was demonstrated by both Dell and HP in their packaging made from leftover wheat straw which were broken down by specialty enzymes, in an organic process similar to that found in a cow's digestive system; compared to traditional chemical pulping, enzyme-pulping uses 40% less energy and 90% less water. In 2014 Dell launched AirCarbon, a biodegradable and compostable plastic from sequestered greenhouse gases, just like plants being made by pulling carbon dioxide out of the air.

Design for reduced material impacts

All manufacturers were found to be actively 'avoiding materials that are known to damage human or ecological health'. All have publicly available chemical substance management policies, and commitments to trace the origins of their tantalum, tin, tungsten and gold supplies to ensure that they are not 'conflict minerals'.

Apple has led the industry in reducing or eliminating toxic substances. It phased out all lead in their solder and display glass, which later became arsenic-free and mercury-free. Brominated flame retardants (BFR) in all plastic enclosures, circuit boards, and connectors were replaced with metal hydroxides and phosphorus compounds. Thermoplastic elastomers replaced all polyvinyl chloride (PVC) in Apple power cords and headphone cables, which also became phthalate-free. Their batteries do not contain lead, cadmium or mercury. However, Apple products have not always been toxin-free; a Greenpeace report revealed that iPhones and iPods contained high concentrations of hazardous chemicals (Santillo et al., 2007).

Samsung has phased out six hazardous substances of concern – mercury, lead, cadmium, hexavalent chromium, poly-brominated biphenyl, and poly-brominated di-phenyl ethers. PVC and BFR have been removed from all Samsung mobile phones, MP3 players and all notebook PC models. Other consumer electronics manufacturers have not yet been successful in completely removing these harmful substances from their products, but all claim to have at least one model which is 'halogen-free', although these claims often exclude power cords. Several have replaced the fluorescent lamps and LCD backlights in their displays and monitors with more energy-efficient and mercury-free LED backlights. The major driver for switching to low-impact materials is obviously the European RoHS, REACH and WEEE regulations (EU, 2006b, 2012, 2013).

'Using materials from reliable certifiers' was commonly practiced by sourcing fibre for packaging and for catalogues from suppliers certified by either the Forest Stewardship Council (FSC) or the Programme for Endorsement of Forest Certification (PEFC). Conflict-free minerals were sourced from smelters certified by the Global e-Sustainability Initiative (GeSI) or by the Electronic Industry Citizenship Coalition (EICC).

'Minimizing quantity of material' was evidenced by the friction-stir welding process for the Apple iMac desktop computer, which saves 68% of material. Most manufacturers also offered 'thin client' computing solutions which use 50% less material to produce than a traditional desktop PC.

'Using recycled or reclaimed materials' was commonly reported. Sony's Blu-Ray disc player contains 76% resin recycled from plastic bottles. Sony developed SORPLAS™ from 99% waste polycarbonate resins and applied this on Bravia LCD televisions and in video cameras, still cameras, and recording binoculars.

The Samsung Universe and Rant mobile phone models contained 69% and 50% postconsumer materials, while the Apple Mac Pro fan assemblies are derived from re-polymerized plastic bottles. Postconsumer recycled fibres are common in electronics packaging. Apples' iPhones and iPod Classics are retailed in boxes containing 90% to 100% postconsumer fibre, while their corrugated cartons have 28% to 50% recycled content; iTunes gift cards, formerly made of PVC, are now made from recycled paper. Nokia reports that 78% of their retail and transport packaging materials contained certified recycled fibres. Dell has packaging cushions made from 100% recycled HDPE from milk jugs and detergent bottles.

Eight manufacturers had examples of 'using renewable resources as materials'. Some Samsung and Nokia mobiles contain bioplastics derived from fermented corn sugar. The Apple AirPort Express enclosure made of industrial-grade rapeseed biopolymer blended with recycled polycarbonate, while the packaging for Apple EarPods is a renewable tapioca paper foam material that dissolves in warm water.

Design for manufacturing innovation

'Minimize manufacturing waste' was reported by all companies on their waste management policies; Dell, Panasonic and Toshiba published their 'zero waste guiding principles'. 'Seek to eliminate toxic emissions during manufacture' was evidenced by the manufacturers' lists of substances to be restricted or banned from their products.

'Minimizing energy or water use in production' and using carbon-neutral or renewable energy sources during production' were also practiced by all but at different levels. The Apple North Carolina data centre is largest end-user owned photovoltaic array installation in America. All other manufacturers used renewable energies in their operations, either by purchasing 100% renewable electricity or having photovoltaic power generation on site.

Design for reduced distribution impacts

All manufacturers had strategies to 'reduce product and packaging weight and volume for transportation'. Acer, HP and LG have eliminated all in-box hardcopy documentation in their products and made them available online. More effective carton design has led to 40% to 60% reduced packaging volumes at Acer and Apple, and between 25% to 40% reductions in packaging weight. The multiproduct cartons for the enterprise products of Dell and HP can hold as much as twice the number of components in the same space as individually packaged products. Microsoft's replacement of its plastic software cases with paper decreased overall weight by 40%.

Design for reduced consumption impacts

Diverse design approaches were found in 'encouraging low-consumption user behaviour' and 'reducing energy consumption during use'. Acer's 'Green Instant On' technology enables users to put their Aspire laptops to sleep and wake it up in less than 2 seconds. All Dell OptiPlex desktop computers are shipped with Energy Smart power management settings enabled. Toshiba's Regza and Sony's Bravia LCD TV models use zero- or near-zero watt when in standby energy saving mode. HP and LG both have online carbon footprint calculators that enable customers to estimate energy consumption and CO_2 emissions when using their products. The Nokia Ovi app reminds the user to unplug when charging is completed, as well as give information on battery status and available standby time and talk time. All manufacturers have products which are Energy Star® labelled and demonstrate various approaches in conserving energy.

Only half of the manufacturers apply 'design for carbon-neutral or renewable energy during use'. LG, Sharp and Samsung released solar mobile phones and Samsung had a solar-charging netbook. Sony has portable emergency radios which are solar-charged and dynamo-powered.

Design for system longevity

'Design for durability' is the most obvious way to make products that last. Dell, Toshiba, Acer and Panasonic-Microsoft offer education-specific laptops which have been designed with extra durability features to endure rough student handling: reinforced shells, shock protection against everyday knocks and drops, spill-resistant keyboards and touchpads, strengthened hinges, and solid-state drives with no spinning parts.

All Dell Latitude, HP Elitebook and Toshiba Tecra laptops are third-party tested to military standards for vibration, dust, humidity, altitude and high temperatures. But the leader in extreme gadgets is Panasonic, whose fully rugged Toughbook laptops and semi-rugged Toughpad tablets are cast from lightweight magnesium alloy and can be used in the harshest environments, such as construction sites, factories and mines. Microsoft Surface tablets have been demonstrated as being strong enough to be ridden like skateboards. The LG G-Flex smartphone has a curved OLED display and casing that flexes and will not get damaged in one's hip pocket, plus a 'self-healing' cover which can repair minor abrasions on its own.

Another strategy for long-lasting products is to 'design for maintenance and easy repair'. Apple is notorious for producing the least serviceable products. In 2009 it introduced the 'pentalobe' screw, a proprietary five-pointed screw apparently designed to prevent self-repairing of iPhones and Macbook Pros. In 2013 iFixit.com – a website that teaches people to repair their own gadgets – listed the top 10 most and least repairable electronic gear. The HP Z1 Workstation PC came out best in this list, with a 10/10 fixability score; its modular construction allows users to replace most major components in five minutes or less (Carlozo, 2013a).

The iFixit list of most difficult-to-repair items was dominated by Apple products in several categories (Carlozo, 2013b). The Apple MacBook Pro Retina Displays were the worst laptops due to their glued-in batteries, proprietary screws, and non-upgradeable RAM memory; the Apple iPod Shuffle and iPod Touch were the worst MP3 players, impossible to open without destroying; and the iPad 4 and iPad Mini were the worst tablets due to their Lightning connectors being soldered to the logic board, so if a connector pin breaks the entire assembly must be replaced.

iFixit also published the reparability scores of smartphones and tablets in the market (iFixit, 2013a, 2013b). Devices with perfect scores were those which were relatively inexpensive to repair, easy to disassemble, and have an available service manual; extra points were given for upgradability, use of non-proprietary tools for servicing, and component modularity. Points were lost if the device is difficult to open or if component replacement is complex. Many Samsung, Nokia and Dell devices were rated highly in the easy-to-repair list. On the difficult-to-repair list were many Apple products, but the worst scores went to the Microsoft Surface Pro, which used excessive glues and screws to hold everything in place.

Design for optimized end-of-life (EOL)

'Design for fast manual or automated disassembly for end-of-life processing' assists in the cost-effective dismantling, segregation and identification of waste electronic components, thereby making them conducive for recycling. Several manufacturers were found to be adopting design for disassembly principles such as: prescribing only one plastic type per component whenever possible; avoiding glues, adhesives or welds on components; using common fasteners and snap-in features but at the same time minimizing the number of fasteners and tools necessary for disassembly; clearly marking the position of screws and indicating the number of screws; affixing material identification labels on plastic parts and components; and affixing recycling label on all batteries.

Another approach is to 'design the recycling business model'. Several manufacturers have gone into partnership with large retail chain stores and charity sites to help recover unwanted gadgets for proper recycling. Most manufacturers also offer free prepaid shipping labels for used products and spent consumables, or trade-ins for working gadgets.

Discussion and conclusion

The examples found clearly demonstrate that consumer electronics manufacturers do apply eco-design strategies using various approaches and at various phases of the lifecycle of their products.

Design strategies for psychological durability – such as 'creating a timeless aesthetic' or 'fostering emotional connection with products' – seem irrelevant in the electronics industry. Indeed when gadgets rise to the status of beloved 'design icons' – for instance Dieter Rams' classic designs of radios, televisions and phonographs for Braun in the 1960s – these objects only survive in our present day either as museum pieces or as 'modern antiques'.

This study was largely based on self-reported information from manufacturers regarding their environmental design achievements, and therefore the potential of being 'greenwashed' by their claims posed a risk to the reliability of the findings. The technology news articles and reports by environmental activism groups provided the balancing act to enable looking at the industry from two different lenses.

Finding a flawless manufacturer in the consumer electronics industry is of course impossible. There will always be aspects of a gadget or production or consumption process which could be deemed praiseworthy, but at the same time there would also be attributes which are undesirable. Many tablets and smartphones are extolled for all the beneficial applications that they provide in our everyday lives, such as saving paper by allowing us to read text online, and yet these products (or parts of them) do not function as long as they ought to, and they are rapidly rendered undesirable by the fancier technologies of the following year.

The Okala, being a structured eco-design tool, helps us objectively see the sustainability improvements which consumer electronics manufacturers have already achieved and continue to work on. Pro-environment advocates like Greenpeace, iFixit, and the European Parliament are to be commended for their continuous efforts in pressuring manufacturers to 'greenify'. Admittedly there are considerably more electronic products that are free from the worst hazardous substances now than in 2006 (Greenpeace, 2014).

Amongst the 47 Okala strategies, one which could be better explored is 'rethinking how to provide the benefit'. As Nokia has demonstrated, creatively thinking 'out of the box' enables us to see the problem with a completely new lens and to approach it in a truly ground-breaking way.

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An understanding of lifetime optimisation through sustainable strategies and intangibility in product and services

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Keywords: systemic design; sustainability; methodologies; life cycle; intangibility.

Abstract: The purpose of this study is to analyse a Concurrent Design Model (CDM), as well as tools and design methodologies such as ABC-Analysis, MET-Matrix, Eco-Design Checklist, LiDS-wheel, Environmental Assessment of Product Strategy, among other means, oriented to support sustainable processes and eco-design, identifying, classifying and evaluating their compatibility with the aforementioned model. Additionally, it seeks to highlight the value of intangibility and immateriality of products and services, under a change of mind set, evolving from product design considered only as a physical fact, to be conceived as a product-system that responds to specific consumer demands. This analysis focuses on addressing sustainability criteria and basic design criteria in the early stages of the design process of sustainable products and services. Factors such as those addressed by Vezzoli & Manzini (2008) and Shedroff (2009) that seek to reach sustainability by optimising the lifetime of both products and services, become then relevant to the study. In the process, different strategies of analysis (such as new concept development, reduction of material usage, reduction of impact during use, among others) are employed. These inputs are managed in the CDM under a multi-criteria vision for the rapid integration of environmental aspects and as a result, premises related to the development of eco-efficient projects are achieved.

Introduction

In the last forty-five years, sustainable design activities have made waste and inefficiency slightly less wasteful and ineffective (Chapman, 2009). However, this limited sustainability perspective is not enough from an evolutionary standpoint of in time projection. Other approaches in terms of alternatives and means to achieve a sustainable society at all levels are necessary, regardless of scale or the productive sectors of activity and service provision, be it local or global.

Design activity has a major responsibility on the impact of the current state of the environment, but also has a vital role in the search of solutions. In the present context, it is imperative to reflect on activities and methodologies for product and service design development in a sustainable way. In fact, as pointed out by Chapman (2009), design methodologies have been rarely committed with the most fundamental questions of sustainability, which is very striking considering the meaning and place of products in human beings lives, and the role of material and immaterial goods in the development of societies.

It might seem a paradox that designers who are responsible for configuring products and their associated services, would not consider the effect and reach of their decisions. This study addresses such issues by means of a methodological approach that helps designers and organizations to navigate towards a society with fewer unnecessary and superficial projects by omission or lack of knowledge, in terms of its environmental performance. The purpose is to highlight increasing trends such as virtualization, and dematerialisation, which some everyday products and services are leading with a high value added.

The systemic model of concurrent design approach

The Design Concurrent Model proposed by Hernandis & Iribarren (1999) consists mainly of an *Outer System* and a *Reference System* (system under study or product-system). The *Outer System* consists of everything that involves the phenomenon that raises the problem or need. It considers the environmental aspects that provide considerations and constraints that influence the design problem. The *Reference System* is mainly composed of three basic subsystems: formal, functional and ergonomic.

These subsystems are at the same level, with no predominance of one over another in order to facilitate a more detailed analysis of the system under study. At the same time, these subsystems comprise other subsystems, components, variables, objectives and elements, considered the maximum degree of proposed disaggregation. In this way, the model proposed in (Hernandis & Iribarren, 1999) leads to a disaggregation by levels. In line with approaches such as those of Munari (2008), who notes that decomposing the problem into its integrating elements means to discover numerous sub-problems and a particular design problem is a set of many sub-problems.

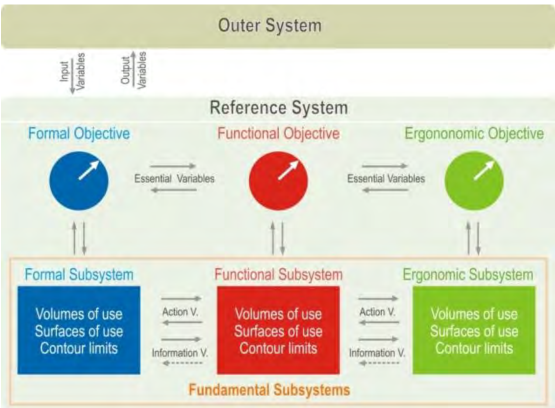

Figure 1. Theoretical modelling. Source: Hernandis & Iribarren, 1999.

Derivation of the Outer System

In a previous study (Rivera & Hernandis, 2012), the authors proposed a way to facilitate and filter the Outer System analysis by focusing all the components into three subsystems: *trend analysis*, *user profile analysis*, and *analysis of references*.

Through this analysis, one can also identify the input variables related to the *material context* of a design problem, others associated with an *immaterial context* in which are considered psychological and psycho-social factors. Factors often ignored and that are also relevant at the time of generating a sustainable design solution. Based on this, a derivation of the Outer System of the CDM, considering *basic design criteria* and *sustainability criteria* for the development of products and services is proposed.

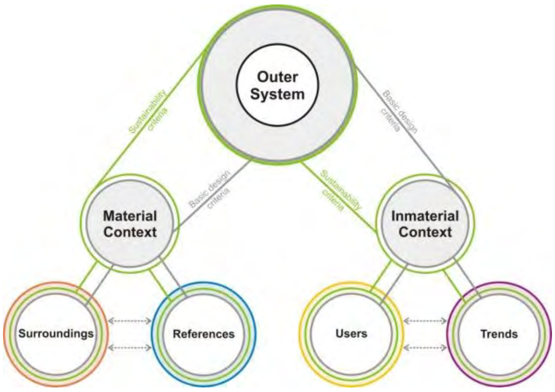

Figure 2. Derivation scheme of the outer system Source: Adapted from Rivera et al., 2013.

In this scenario, in relation to the criteria and qualities of the related phenomena of research, the material and the immaterial context are raised, as a way to identify criteria that validate the assumptions or knowledge about the concepts of perceived reality.

Analysis of tools and strategies for sustainable design

In a previous study, the authors reviewed and analysed some tools and strategies for sustainable design and eco-design for the integration of environmental premises into the design process (Rivera & Hernandis, 2012). The analysis helped to identify within these tools some *Sustainability Criteria* that can be related with the product life cycle. Therefore, it becomes possible to observe its relation with the *Basic Design Criteria* and to consider an approach for the development of products/services from the early stages, making use of a systems approach that considers sustainability at its core. Figure 3 shows a classification of eco-design and sustainable design tools applied to the product development process. According to Tischner (2001), these tools are adapted based on two criteria:

- Requirements of complexity and time requiring tools to be used, and
- The purpose of tools in terms of:
  - Environmental analysis of strengths and weaknesses,

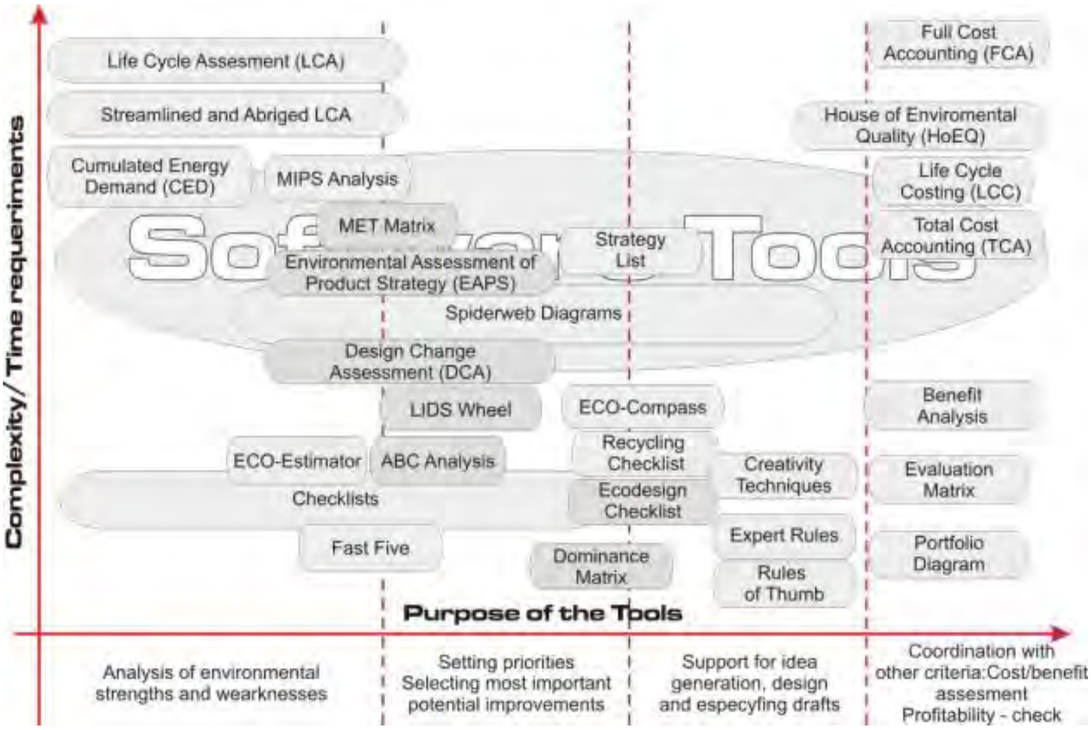

Figure 3. Eco-design and sustainable design tools. Source: Adapted from Tischner, 2001.

- Prioritization and selection of the most important potential improvement;
- Assistance in the generation of ideas, design and draft of specifications, and
- Coordination with other criteria: cost-benefit, feasibility, economic and similar studies.

This study analyses the compatibility of tools and strategies for both sustainable design and eco-design, within the design process. Sustainability criteria is considered in the early stages of the design process of a product/service. Thus, other tools and strategies that tend to intervene in later stages when only minor changes can be made, were not taken into account. Sometimes, such changes can lead to a complete redesign of an existing product. Among the tools considered in the analysis, some of them allow the selection of environmental improvements. These improvements can be carried out at the same time, and are compatible with the *form*, *function* and *ergonomics* requirements of CDM.

For the purpose of this study, the classification proposed by Rieradevall & Vinyets (1999) and Byggeth & Hochschorner (2006) was used. Time and ease of implementation of fifteen different types of eco-design tools are analysed. From the previous classifications seven tools are selected in order to recognize whether they meet the purposes of being easy to use, require extensive quantitative data and does not require much time to implement. The tools are *ABC Analysis, MET-Matrix, Eco-design Checklist, Dominance Matrix, LiDS-Wheel, Environmental Assessment of Product Strategy* and *Design Change Assessment*.
After describing them, they were evaluated by means of a map based on the time required for its implementation and the complexity of the tool (Figure 4).

The analysis considers that the LiDS-Wheel principles (Brezet & van Hemel, 1997) can be applied to the CDM (Hernandis, 2010), due to the following aspects:

- Early integration of the environmental aspects into the product and process development.
- Flexibility to incorporate environmental improvements into the conception.
- A life cycle approach that allows the impact analysis of the product over the environment.

A multi-criteria approach that can be combined with the traditional requirements of form, function and ergonomics of the CDM

Tool	Reference	Environmental Assessment	Subject of study	Life cycle perspective	Purpose	Procedure
ABC-Analysis	Tischner et al (2000) based on Lehmann (1993)	Subjective Qualitative	Product/ function	Yes	This tool can be used for assessment of environmental impacts of a product.	The product is evaluated on 11 different criteria and classified in one of the following grades: A=problematic, action required, B=medium, to be observed and improved, C=harmless, no action required.
MET-Matrix	Brezet y Van Hemel (1997)	Subjective Semi-quantitative*	Product/ function	Yes	The purpose of the tool is to find the most important environmental problems during the life cycle of a product, which can be used to define different strategies for improvement.	The environmental problems should be classified into the categories Material cycle (M), Energy use (E), Toxic emissions (T).
EcoDesign Checklist	Tischner et al (2000)	Objective Qualitative	Product/ function	Yes	The checklist helps to identify the main environmental problems along a product's life cycle.	The user has to evaluate whether the solutions in the checklist are good, indifferent, bad or irrelevant.
Dominance Matrix or Paired Comparison	Tischner et al (2000)	Subjective Qualitative	Product/ function	No	The purpose of the tool is to set up a ranking of competing criteria or solutions, e.g. competing demands on a product or competing ecological requirements.	Is performed a systematic comparison between the different alternatives. Each individual alternative is compared qualitatively with all other alternatives.
LiDS-wheel	Brezet y Van Hemel (1997)	Objective Qualitative	Product/ function	Yes	A tool to give an overview of environmental improvement potential to the designer. Eight environmental improvement strategies are utilized in the tool	The tools are: selection of low-impact materials, reduction of material usage, optimisation of production techniques, optimisation of distribution system, reduction of impact during use, optimisation of initial lifetime, optimisation of end-of-life system and new concept development. Data from a reference product are entered into the diagram and according to the eight strategies; improvement options for the product should be identified.
Environmental Assessment of Product Strategy	Rieradevall, J. & Vinyets, J. 1999	Subjective Qualitative	Product	Yes	Perform the positioning of an existing product and eco-friendly product project, based on the strategies for environmental improvement.	The design team makes a qualitative analysis of the environmental improvement actions currently associated to the product and which lacks, then a qualitative assessment of these data is performed and finally the results are expressed graphically.
Design Change Assessment	Rieradevall, J. & Vinyets, J. 1999	Subjective Semi-quantitative	Product/ function	Yes	Design or redesign products with general objectives of reducing the amount of waste and its toxicity.	A basic methodology that allows identify problems and prioritize corrective actions in the field of waste is used.

Note: *The results and data can be both quantitative and qualitative.

Table 1. Classification of environmental systems analysis tools selected.

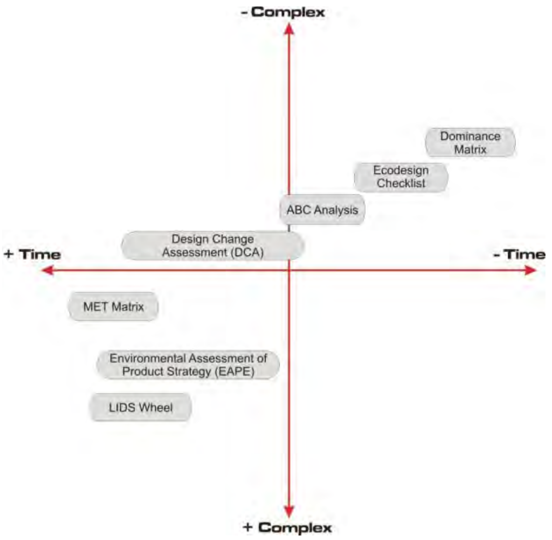

Figure 4. Map for the evaluation of tools (according to time and complexity). Source: Adapted from Rivera & Hernandis, 2012.

It is worth to highlight that the essence and the *LiDS-Wheel* strategies are reflected in other methodologies and concepts, such as those generated by Vezzoli & Manzini (2008), Shedroff (2009) and Crul & Diehl (2006). Later, these concepts will be considered to support the proposed approach.

Sustainability criteria of LiDS-Wheel in design methodologies

The LiDS-Wheel is a tool that allows an overview of the potential for environmental improvement through eight strategies. This tool is used in product redesigns, where guidelines for eco-design and sustainability are determined up from the analysis of the current state of a product.

Much of these tool strategies are reflected in other methodologies with sustainability and eco-design criteria, such as those developed by the UNEP and Delft University of Technology. Their strategies are included in *Design for Sustainability: A practical approach for developing economies* (Crul & Diehl, 2006). Already in the 70's and 80's, and with publications such as the report on the situation of the humanity in *The Limits to Growth* (Meadows *et al.* 1972), started a warning against the destabilization of the industrial society.

Considering the above and as stated by Bürdek (1994), some ecological requirements (waste collection, pollution reduction, reuse of materials, duration and repair of products, to say a few) can be related to the establishment of the sustainability criteria in the early stages of the design process. The classic view of waste that leads us to consider using economic arguments to address the designer's work, the design for obsolescence, as coined by Bonsiepe (1978).

In the same way that Baran & Sweezy (1968) state that *"...the variations in the products increasingly fallacious, variations in consumer goods, increasingly less satisfactory and more expensive, the spread of superfluous accessories...",* lead designers to target their approach, in addition to the basic fields of activity as the aesthetic and economic, towards the ecological, social and emotional problems. Moreover, as for the satisfaction of user needs, considerations were purely functional, as suggested by Löbach (1981), focused solely on the process of using.

Subsequent approaches, such as those of Vezzoli & Manzini (2008), argue that proper identification of environmental priorities is crucial for guiding design efforts and eventually establishing the selection criteria for alternative solutions. A proposal based on the consideration of some of the Life Cycle Assessment (LCA) components (SETAC, 1992) establishes a design criteria and guidelines that can be summarized in seven basic concepts:

- Material consumption minimization
- Energy consumption minimization
- Toxic emission minimization
- Renewable and bio-compatible resources
- Product lifespan optimization
- Improvement of the lifespan of materials, and
- Design for disassembly.

These design criteria have key points in common with strategies like the LiDS-wheel (Brezet & van Hemel, 1997), as both tools consider stages of product life cycle. However, like the LCA, the initial phase of its implementation the design process produces mainly qualitative data, the reason it could not determine the actual environmental impact of future products and services (Rivera, González, & Hernandis, 2013).

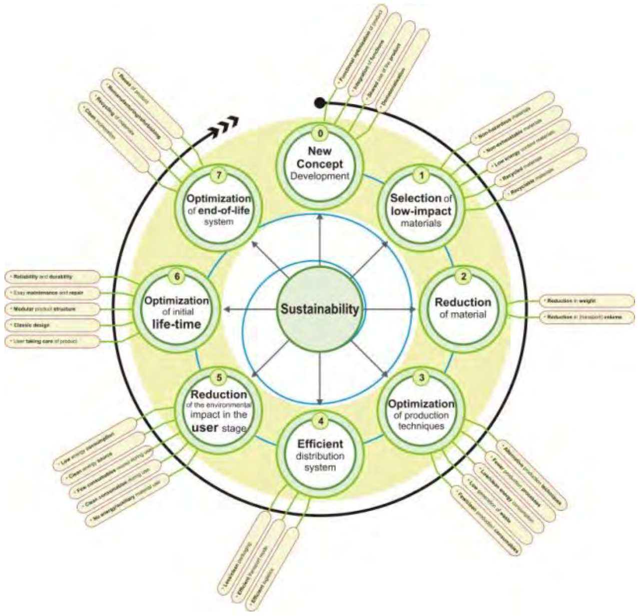

Figure 5. LiDS-Wheel strategies. Source: Adapted from Brezet & van Hemel, 1997.

Figure 5 shows the LiDS-wheel strategies (Brezet & van Hemel, 1997) according to their relation with the product system and the options that can be chosen for each strategy. The eight LiDS-wheel strategies are divided into three different levels, according to its product system relation (strategies 7 and 6), its relation with product structure (strategies 5, 4 and 3) or its relation with product components (strategies 2 and 1). The way to represent the strategies with a spiral is due to the cyclical approach these strategies should have towards sustainability. It is thought that these strategies should be focused not only on the redesigning of an existing product/service, but in the generation of new products, services and concepts in which sustainability criteria are applied from the early stages of the design process.

In a previous study (Rivera, González, & Hernandis, 2013), the integration of a tool or methodology for sustainable design or eco-design was performed by applying the principles of the wheel of strategies LiDS-wheel in the concurrent design model, since its principles can be applied at the conceptual stage in the development of a product and a process. In the analysis of the input variables, characteristics of the project are identified and are defined the requirements and previous determinants in its general aspects before performing the subdivision into the basic subsystems. In this step besides analyzing requirements and determinants, sustainability criteria into CDM must be applied.

The requirements and needs resulting from the outer system analysis were related to the variables coming from the strategies of the LiDS wheel. These are shown in the diagram in the form of capsules while determinants are shown alongside these capsules containing possible solutions to the requirements of form, function and ergonomics.

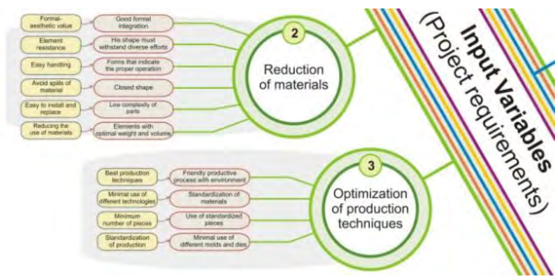

Figure 6. Study Case - Requirements & Determinants. Source: Adapted from Rivera et al., 2013.

Figure 6 depicts indicating how sustainability criteria are related to the possible solutions. The circles indicate the number of the LiDS-wheel strategy each requirement would be associated. As can be seen in this case study, the integration of some of LiDS-Wheel strategies with input variables - project requirements - into CDM, where the option for more sustainable is identified to comply with project requirements.

Action	Subject	Approach
Dematerialise	Products and Services	Alternative concepts Management
Digitalise		
Optimize	Lifespan	
	Efficiency	
Use	Simulation systems	
	Digital supports	
	Digital tools	
	Modularity	
	Multifunctionality	
Enable	Updated (adaptability)	
Adapt to	Cultural and physical changes	
	Surroundings - environments	
Update	In-situ	
Reduce	Structural stiffness	Materials Management
	Thicknesses	
	Scraps and wastes	
	Packaging	
Recycle	Resources	
	Materials	
Use	Renewable	
	Bio-compatible	
	Bio-degradable	

Table 2a. Approaches for the design of sustainable products and services.

Action	Subject	Approach
Minimize	Energy	Production Management
	Technologies	
	Machinery	
	Volume	
	Transport	
	Maintenance	
	Weights	
Compact	Components	
Reduce	Storage	
Assemble	In-situ	
Decentralize	Processes	
Encourage	Local consumption	
Retrieve	Energy	
	Components	
Save	Energy	
Avoid	Remote working	
	Toxic - harmful	
Replace	Components	
Reduce		
Simplify		
Eliminate	Unions and assemblies	
Enable	Maintenance	Use management
	Access to component	
	Disassembly	
	Cleaning	
	Replacement of components	
	In-situ repair	
	Re-use	
	Access to component	
	Secondary use	
	Remanufacturing	
	Recycling	
Improve	Resistances in the components	
	Lifespan (materials)	
	Resistances	
	Aesthetics	
Replace	Standard parts	
Use		
Re-use	Packaging	
Recycling		
Retrieve	Performance materials	End-of-life management
Avoid	Composite materials	
Use	Efficient technologies	
	Geometric solutions	
Enable	Collection	
	Transport	
Design	For retrieval	
	For reduction	
Improve	Stacking	
Inform	On its removal (to the user)	
Identify (in materials)	Age	
	Recycled	
	Additives	
	Standard system	
	Easily visible places	
Minimize	Incompatible materials	
Use	Integrate functions	
	Only one material	
	Compatible materials	
	Same or compatible unions	
Enable	Composting	
Use	Degradable materials	
No combine	Non-degradable and degradable	
Separate		
Avoid	Harmful substances	
	Harmful additives	
Separate	Materials	
Reduce	Disassembly and separation operations	
Prioritize	Materials and components disassembly	
Use	Modularity	
Include	Route disassembly	
Consider		

Table 2b. Approaches for the design of sustainable products and services (continuation).

As a result of the above analysis, the compatibility study with the CDM is addressed. In the process, an analysis of the methods and concepts such as those proposed by Vezzoli & Manzini (2008) and Shedroff (2009) were done. Keywords extracted were related to LiDS-Wheel, and can be essential for the development of products and services with sustainability criteria. Through this analysis, one can identify the key actions and subjects that are directly related to the concept of design for sustainability. It ranges among those related to materials and processes, to those related with the emotional component to be widely regarded when this objective wants to be achieved.

Table 2a and 2b identifies the actions and subjects considered by some design methodologies for sustainability. It recognizes key points that allow the definition of *Sustainability Criteria*, which may be related with the *Basic Design Criteria*, to allow its application in the CDM. This classification is also divided into five approaches: *Alternative concepts management*, *materials management, production management, use management,* and *end-of-life management*. The idea is to identify and determine the timing of the life cycle of a product or service where sustainability criteria may be implemented.

Conclusions

Through the analysis of tools that consider sustainability criteria, and approaches of product design for sustainability, this study focused on life cycle that can identify the *Sustainability Criteria*.

It was highlighted how these criteria relate to the *Basic Design Criteria* of the CDM, from the initial stages of design process. Results from the previous analysis suggest that a product and/or sustainable service is characterized by:

- Change their format and switch from a *physical* to *virtual* product and/or *digital* in any of its components and functions.
- *From* being *product* change its mode to *service*.
- To *tend* to its *dematerialization* or any of its functions and components.
- *Integrate functions*, reducing the total number of materials and components.
- Avoid unnecessary and useless features and components.
- Generate a greater *emotional bond* with the user/consumer.
- Have a *reliable* design or *configuration* with an appropriate lifespan (no planned obsolescence).
- Use *digital tools* in design, modelling, prototyping, documentation, communication and presentation.
- *Use* materials *effectively* in production, consumption, maintenance and end of life.
- *Minimize* or *avoid* energy consumption during production, storage, transport and disposal.
- Use *efficient* technologies and machineries which *optimize* the production process.
- Provide *information to the user* about their materials, components and the modalities of its end of life and/or disposal.
- Divide the structure into easily handled, separable and replaceable *modular components*.
- *Enable* its *updating* (software and hardware) for its reuse and/or secondary use.
- Allow its *maintenance*, *repair* and/or *remanufacturing*.
- Be designed to facilitate its *retrieval* and *recycling*.
- Take into account *environmental issues* such as biodiversity, emissions, renewable resources.
- Take into account *emotional*, *functional* aspects and *feelings* of user/consumers as co-creators.
- Consider changes in *behaviours*, *attitudes*, *habits* and *lifestyles* of society (trends).
- Take into account the *social component* of workers and communities that are behind its development and implementation.
- Consider in addition of *needs* and *global features*, *needs* and *local features*, so that the solutions adapt to each environment.
- Enable their *adaptability* to cultural and physical changes in diverse environments.

It is worth highlighting that besides the traditional triad of sustainability (economic, social and environmental aspects), the users/consumers emotional aspects are relevant. These issues can be related with the development of successful sustainable products and services, in which dematerialization, reliability, durability and virtualization through intangibility are possible, and must be addressed from the early stages of design with the appropriate methodologies. The study suggests that instead of less demand on design, more conscious design is expected in opposition to the mass-production of superfluous and unnecessary products and services.

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Driving in the wrong lane: towards a longer life-span for cars

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Keywords: car longevity; product life-spans; car design; vehicle development.

Abstract: Within the context of product longevity, one especially impactful and ubiquitous product demands further research: the car. Car longevity has been addressed in the context of product life extension and product lifetime optimisation but there have been a few studies on car longevity in the context of business and none specifically from an industrial design context. This paper presents initial findings from preliminary interviews with key industry representatives such as car designers and engineers. It discusses the barriers to and opportunities for designing a car with a longer life-span. This and further data will later be analysed in order to produce a design framework to inform car designers on life-span and usage optimization through design. Strategies such as increased longevity or use-intensity can potentially reduce the throughput - and thereafter the consumption - of cars. Such a shift in the automotive sector would support the transition from a linear economy to a more sustainable one. The initial findings, however, suggest that a longer life car is not an uncompromised solution and important concessions would have to be made in order to make this an acceptable product.

Introduction

Increasing the life-span of cars as a way of diverting products from being scrapped has been highlighted in a report by the O.E.C.D. (1982), and also discussed by Ware (1982), who envisages a maintenance plan to keep used cars running for longer. More generally, Cooper (1994) proposed going beyond recycling consumer durables such as cars in order to reduce environmental impacts.

Nieuwenhuis (1994) has noted that doubling the life-span of cars from 10 years to 20 years would potentially reduce the volume of vehicles produced and dismantled, and thus associated environmental impacts. Allwood and Cullen (2012) similarly suggest that vehicles can last up to 20 years, potentially reducing material and energy demands. However data shows that vehicles in the UK are lasting, on average, around 13 years (Oguchi and Fuse 2014). In order to enable longer life products Stahel (2010) identifies three conditions that need to be in place to make this possible: durability, function and performance. These, he argues, are a prerequisite for product longevity, leading to design for ease of repair, maintenance and technological upgrade.
Other authors argue that for energy-using products such as passenger cars, with environmental impacts during use phase, designing a user-intensive solution might be the preferred option, even though this may imply earlier product replacement (Van Nes and Cramer 2006; Vezzoli and Manzini 2008).

Whether or not increasing vehicle life-spans has environmental benefits (Kagawa, Tasaki *et al.* 2006), vehicle manufacturers currently engaged in longer product life-span activities such as remanufacturing are motivated by spare parts security, warranty issues, market share, brand protection and customer orientation (Seitz 2007).

Methodology

This paper is based on a preliminary analysis from seven in-depth semi-structured interviews with automotive designers and engineers. Subjects came from a variety of different automotive companies and countries ranging from mass-market, premium and high premium manufacturers, a large multi-national tier-one supplier and a vehicle testing consultancy, reflecting different company cultures and approaches to vehicle design in order to avoid bias. For confidentiality reasons they will be named D1 (Designer 1) E1, (Engineer 1) and so on (Appendix 1). A balance between car designers and engineers was achieved in order to provide a suitable breadth of opinions. The interviews were made on location, where possible, or via video-call. The duration of the interviews ranged between forty minutes to one hour. An open question approach was used (Robson 2002) in order to explore impacts of designing for longevity. All interviews were voice-recorded and transcribed. The analysis was made by clustering answers against codes identified in the interviews (Bryman 2008); these clusters were then classified into barriers and opportunities.

The questionnaire focused on the adoption of longer life-spans for passenger cars in the design process. It was divided into four indicative questions to explore the barriers and opportunities of designing cars with longer life-spans. Barriers and opportunities described here are not exhaustive but were considered significant.

The first question related to the currently accepted process of vehicle design and whether designing for longevity would impact this process. The next question related to the vehicle itself, especially features such as modularity, ease of repair, easy disassembly and upgrading (Gehin, Zwolinski *et al.*. 2008; Stahel 2010 and Go, Wahab *et al.*. 2011). A third question focused on a 20 year life-span car (Nieuwehuis 1994, Allwood and Cullen 2012) and the designer/engineer approach to its design. The final question asked how interviewees would design an optimal life-span car with less material; this was intended to summarise the interviewee's views on vehicle longevity.

Barriers and opportunities

A range of barriers to and opportunities for longer lasting cars were identified during the interviews. Some of the clusters identified relate to one or more codes, making the separation between barriers and opportunities rather challenging (Appendix 2). However, initial research findings show that to achieve a longer life-span car, important compromises have to be made by consumers and industry.

Duty cycle

Three interviewees argued that for longer life-span cars, reinforced structures are needed to deal with extra years in service. To achieve this, engineering interviewees affirmed that car structures and vehicle systems would have to be strengthened, adding more material in order to manage the extra life-span. This would have rebound effects on energy spent in manufacturing and usage. Interviewees D1 and E3 stressed that heavier vehicles may not meet emissions targets set by the EU. E4 confirmed evidence from literature that car structures nowadays can easily last more than 20 years. E1 suggested that vehicle manufacturers have data on longevity from taxis suggesting that in some cases taxis clock-up one million miles.

Despite this, structural safety evolution is reaching a plateau. Safety and crash rates are being driven by electronic systems such as pedestrian protection or collision-avoidance systems. E4 pointed out that if such devices can successfully avoid collisions at low speed, sacrificial low speed crash structures such as bumper structures can be eliminated, reducing material and weight.

Vehicle weight

Excessive material in cars has implications for weight, and thus energy use. Carrying excessive weight for 20 years or more is wasteful and creates a vicious cycle of more power to carry more weight, leading to bigger brakes, bigger cooling systems and so on (D1). However, interviewee E4 pointed out that steel operating in an infinite fatigue region - i.e. an over-engineered structure able to support "the amplitude (or range) of cyclic stress that can be applied to the material without causing fatigue failure" (Beer, Johnston *et al.* 2004) - will be able to have a prolonged life. This suggests that a very simple yet robust structure would be desirable.

Asked about lightweight materials as alternatives to steel, D1 suggested that aluminium and carbon-fibre are energy-intensive to produce, potentially offsetting the benefits of a longer life-span with more energy usage during production.

Material usage

Material and embodied energy are closely associated (Allwood and Cullen 2012). Steel was identified as the most energy efficient and cost effective material for structural purposes (D1). Carbon-fibre and (virgin) aluminium may push the demand for energy upwards if widely used.

E4 stressed that conventional materials, such as steel, and technology used, as in internal combustion engines, are often underestimated and sometimes possess potential to be improved. High-tensile strength steel has seen an uptake in recent years especially in car structures (Heuss, Muller *et al.*. 2012). Recycled aluminium is also finding its way into lightweight structures (Jaguar Land Rover Corporate 2013).

Vehicle packaging size was considered an area with potential for optimisation by D1, E2 and E4. Smaller cars were identified as better packaged than larger ones; if small vehicle packaging is pushed further, gains in material reduction can be reaped effectively (E4). D3 and E3 identified corrosion protection for steel, currently guaranteed for 12 years against perforation, as suggesting that extending the life-span of cars can stimulate the development of better corrosion protection systems.

Design and development

Design has been identified as a key enabler for longer life products, capable of standing the test of time and overcoming fashion (Cooper 2005, 2010). Interviewees indicated that opportunities for designs that are visually simple (D1), providing basic equipment with options for personalisation, can potentially create greater attachment and more user-machine interfaces (D2). Designers could be constantly involved in one ongoing project, especially if there is better interaction between them and the customer due to modularisation and upgradability (D2).

3D printing was identified as an opportunity for personalisation, although only for non-structural interior parts (D2). Another opportunity identified was design for disassembly of parts (D1), although this could also act as a barrier by making visible, in order to facilitate access, unattractive components that are conventionally away from sight (D1 and E4), penalising overall styling. D1 suggested that this kind of a longer life-span vehicle would be suited for developing countries, perhaps built locally, but would not be attractive to the automotive industry in industrialised countries.

Upgradability and modularity

Upgradability and associated modularity are often features of durable products. Upgrading opportunities were seen as limited by several interviewees. The barriers to upgradability and the necessary modularity were said to concern technology and legislation anticipation (D1, E1, E4) and technical obstacles (D1, E1, E2, E4). For example, the ever-changing criteria in legislation meant that from one product generation to another, currently around eight years, upgrades can only be achieved for validation with new structural architectures (E3) as, otherwise, the whole vehicle structure is seriously compromised in its integrity, performance and safety protection. Powertrain upgradability was also seen as a barrier; fuel cells require more cooling capacity than internal combustion engines, hindering aerodynamics (E4). One opportunity identified was component upgradability. These could be designed to have limited life-spans, as in the aerospace industry, and replaced when scheduled (E4).

D3 exemplified barriers to modularity in dashboards; for comprehensive modularity, hidden subsystems such as passenger air-bags would have to be separated from the dashboard structure and become more visible. D1 remarked that cars are designed with a certain style and components would have to fit structures with some degree of compromise. In order to become modular, car styling would be compromised and the interviewee was sceptical about the market accepting this.

Service, maintenance and disassembly

Repair and maintenance is an important element in strategies for longer product life-spans (Cooper 2005, Bakker, Wang *et al.* 2014).

In the case of cars, opportunities were said to lie with replaceable and easier to access panels, flaps and trapdoors for parts that are currently difficult to access. One interviewee suggested that a ‘back-to-basics’ vehicle would be easier to repair with fewer tools and with very basic repair skills (D1), helping also to reduce costs. He gave the example of the original Land-Rover as a vehicle which is simple to repair in any part of the world. He also stressed that safety and market acceptance may be challenging; attachment points such as bolts and screws would need to be visible for easy access and repair. Such a vehicle would also make few concessions to styling. E4 argued that compromises in areas such as reparability have to be made for the benefit of safety and/or regulation.

Increasing preventive maintenance was mentioned as an opportunity (E2). Another would be a change in the image and acceptance of the ‘old’; for example, fringes of the classic car market value the patina or discolouration in leather seats (D2).

Production
Changes in design and development would also impact upon production. Vehicle modularity would raise challenges, such as increasing job times per part and manufacturing footprint (E3) and complexity of assembling fasteners, hinges and extra parts for easier access to repair, disassembly and upgrade (D3, E4). These changes in production would in turn increase risk and costs (D3).

On the other hand, extending vehicle life-span and product lifecycle offers potential benefits such as lowering the frequency of tooling investment in production. However, any savings in production would need to offset investment and risk costs, such as loss of market share due to longer product lifecycles (E3). D1 proposed that such vehicles would have to be produced on a more localised scale, meet local needs, and be flexible enough to be changed according to market requirements.

Regulation
Regulation was pointed out as a key barrier to longer life cars by all interviewees except one.

Future changes in regulation affecting a car intended to last at least 20 years are difficult to foresee (E4). E2 noted that emission targets are ever-changing.

E4 identified changes in design requirements due to regulation (e.g. pedestrian protection), which imply that structures may need to change. This might suggest that longer life-span cars may be considered not fit for purpose after a certain period of time. In addition, legislation is less predictable in terms of the driveline/powertrain than a few years ago.

D3 suggested that regulation is an obstacle to differentiation in vehicles and that a different concept would have to be considered in the light of ever-tightening regulation, implying greater conformity.

Discussion
The research findings suggest that concessions may have to be made in several key areas in order to design a longer life-span car. They also confirm that further research is needed to understand consumer acceptance of such vehicles.

Increasing material in cars impacts on production and job times to weld and assemble. Developments in electronics for safety may enable the elimination of some structural parts and components, although reliance on electronics to control safety systems may have adverse effects if accidents occur due to system failure.

There is a lack of comparative data between traditional and light-weight materials for longer life-span cars. Light-weighting materials are desirable, to overcome structural reinforcement barriers, but are more energy-intensive to produce. Steel is more energy efficient in production but there are obvious weight disadvantages that impact on overall emissions over the longer term. In order to understand whether using steel or lightweight materials would be more appropriate to achieve longer car life-spans, a life cycle assessment would be needed to compare the environmental effects. If steel was found preferable, then corrosion protection systems would have to be guaranteed for longer than at present.

Disruptive technology is a considerable obstacle to the designed interface and hardware. Longer life-span cars would not be able to integrate all disruptive technology, especially if it made cars more energy efficient.

The industry also faces uncertainty with powertrain technology. Technology road maps point to hybrids with an electrical powertrain having a predominant role and electric vehicles, still limited in their range performance, being outmoded by fuel cells (Automotive Council 2013). However, electric vehicle batteries are evolving to be smaller and lighter. If battery interfaces remain the same, then weight reduction advantages will come forward, potentially enabling product life extension. The challenge to accommodate, in one architecture, all powertrain technologies and upgrading them throughout the life-span of the car remains very difficult for the industry. Performance can be affected by system incompatibility. Upgradability would therefore have to be limited to a few selected components, such as non-structural panels or software.

Interviewees were generally unfavourable towards structural modularity. Making a structure as effective as possible and trying to optimise each component would reduce its performance. Reversible fixing points such as bolts, screws and fasteners would be needed, together with reinforcement materials, adding weight and compromising safety, comfort and emissions. Increasing the number of parts for access would add complexity, longer assembly times and threaten earlier failure. Limited-life components could potentially be made with less energy intensive materials, offsetting increases in structural robustness.

Such barriers to production can potentially lower profits, contributing to industry transition failure (Wells and Nieuwenhuis 2012). New approaches to vehicle design and production would need to accommodate these changes without compromising the product and company profits, which may only be possible in lower volumes and with simpler technology (Wells 2001). If such a car was to be made of lightweight materials such as aluminium or carbon-fibre, power generation could be provided by renewable energy to manage the higher energy demand.

Further research on maintenance is needed. Interviewees suggested that frequent maintenance prevents earlier component failure. However, higher frequency of servicing, material and energy usage needs to be carefully analysed to understand any environmental disadvantages. It is not clear if it these would be offset by longer car life-spans. Records of longer lasting cars (e.g. taxis) which have regular maintenance schemes could be analysed.

Market barriers were also addressed. The industry is sceptical about consumers accepting a long life-span car, noting that data shows an increase in car production worldwide (OICA 2015). The market offer of short leasing schemes of two to three years can be a barrier together with the culture of fast consumption of consumer goods. The challenge may lie in the vehicle owner's perception of wear and 'old'.

Longer term regulation changes cannot be foreseen. Predicting its direction in the short term is not so difficult, but forecasting for two decades ahead is challenging. Ever-shifting parameters in standards for design, safety and emissions make it a barrier to change. In theory modularity could overcome this problem, but technical barriers may make modularity (and upgradability) problematic.

Conclusions

It was evident from an initial analysis of these interviews that longer life-span cars are far from being uncompromised, and concessions in styling, size or basic system technologies may need to be accepted by consumers and industry in order to make them feasible. However, despite the barriers encountered, opportunities were found. The challenges posed by a longer lasting vehicle could potentially stimulate companies to find new solutions for weight and complexity.

Further research needs were identified: comparative LCAs of light-weight materials in longer life-span cars; a policy framework suitable for autonomous safety systems which would enable elimination of some safety structures and reduce weight; impacts of limited-life components on cost and remanufacturing; consumer perceptions of wear and 'old' in cars; market research for the uptake of longer life-span cars; explaining the disconnect between industry capability of producing cars made to last over 20 years and current practice of cars being scrapped by consumers in the UK at an average age of 13 years.

This research project is ongoing and alternative solutions for excessive waste from discarded vehicles, such as user-intensive cars, are also to be addressed.

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Appendix 1. List of interviewees.

Reference	Job Title	Type of Company
Designer 1 (D1)	Head of Concepts	High-Premium Manufacturer
Designer 2 (D2)	Vehicle Interior Designer	High-Premium Manufacturer
Designer 3 (D3)	Senior Interior Designer	Generalist Manufacturer
Engineer 1 (E1)	Senior Manager Corporate Engineer & RD	Tier 1 Multinational Supplier
Engineer 2 (E2)	Principal Materials Engineer	Premium Sports Car Manufacturer
Engineer 3 (E3)	Chief Engineer Body Complete	Premium Manufacturer
Engineer 4 (E4)	Global Business Director - Former Technical Director	Vehicle Testing Consultancy

Appendix 2. Barriers to and Opportunities for Longer Life-span Cars

	Codes	Barriers	Opportunities
Longer Life Vehicle	**Duty Cycle**	- Heavier structural reinforcements - More energy spent in production	-
	Weight	- Inefficient transportation of excessive mass - Heavier systems and subsystems (e.g. brakes)	- Simpler but more robust structure - Infinite fatigue region operating materials - LCA of lightweight materials in longer life-spans
	Lightweight materials/ Material usage	- Lightweight materials more energy intensive to produce	- Structural recycled aluminium - Conventional materials potential often underestimated - Smaller vehicle packaging - Stimulus for longer-life corrosion protection systems (currently 12 years)
	Design and development	- Easier disassembly will bring to the fore "invisible" components… … hindering aesthetics	- Visually simpler solutions - Basic equipment... - ...providing scope for personalisation…. - … enabling attachment - More user interfaces - 3D printing - Easier disassembly of parts - Greater degree of interaction between designer and consumer - Ongoing project
	Ownership/ usage	- Consumers will not necessarily keep their cars for longer	- Personalisation - Direct feedback to designers
	Upgradability/ Modularity	- Frequent changes in regulations/standards - Cost - Structural modularity - Foreseeing effects of disruptive technologies	- Upgradability of non-structural parts (wings, door panels) - Quicker response to customer demand - Limited lifetime parts built with less energy.
	Service/ maintenance/ disassembly	- Increase of access to parts adds complexity (e.g. flaps, hatches, etc.) - Longer life may increase failure rates - Compromises in reparability favouring safety	- Back to basics cars easier to repair - Increase in preventive maintenance - Redefine the image of old and used
	Production	- Increase in job times due to complexity of built-in accessibility - Risk costs in changing production processes - Energy demand in lightweight materials	- Less tooling costs if vehicle is in production for longer. - New approach to vehicle design - Local/more flexible production
	Market	- Market acceptance of aesthetics compromise - Risk of losing market to competitors - 20 yr Market trends forecasting	
	Regulatory	- Foreseeing regulatory evolution in a 20 yr window	
	Business	- No interest from the mainstream manufacturers in changing the established business model - Panel upgrading has been tried before unsuccessfully	

Product leasing: a strategy to allow manufacturers and customers to benefit from elongation of product life

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Keywords: industrial demand growth; car service life; lifelong car leasing; life extension; environmental implications; financial evaluation.

Abstract: International development means that the number of people who can be considered as consumers is projected to triple by 2030. This is good news but if we consume goods in the same way as people did in the 20th Century it will lead to an unsustainable rise in industrial greenhouse gas emissions and contribute towards material scarcities. The old axioms of maintaining profits by high turnover of low profit margins goods, and boosting demand by releasing new models needs to be reconsidered for a sustainable future. The key point is that people's needs are met by using goods not just acquiring them. One way of reducing the demand for new goods is to use old ones for longer. This study looked at second hand car data and concluded that cars are scrapped when they have a low market value not when they are worn out. It follows that if the second hand value can be raised, cars could potentially be used for longer. One way of increasing the value of a second hand item to a business is to value it as a future profit generator as well as for its market value. A long term lease model has been considered and found to be potentially beneficial to both the supplier and customer.

Introduction

There is agreement amongst governments that Green House Gas (GHG) emissions need to be reduced (UN, 2012). The International Energy Agencies 450 scenario (IEA, 2013) shows the emission trajectories needed to limiting the rise global temperature to 2° C by 2100. It calls for a 5% reduction in industrial emissions (excluding those associated with electricity use) from 2010 levels by 2035. It has been estimated that the number of people who will be wealthy enough to enjoy a developed world lifestyle will rise from 1.8 billion in 2009 to 4.9 billion in 2030 (Kharas, 2010). Assuming this results in a proportionate increase in the demand for goods the emissions per unit of production in 2030 (E_{2030}) will have to meet the following condition for the emission target to be met:

$$E_{2030} = \frac{1.8}{4.9}\frac{95}{100}\,E_{2010} = 0.35E_{2010} \quad \text{Equation 1}$$

An alternative strategy is to get more use out of the goods we produce so we need less of them (Cooper, 2005). This can be done by either sharing them between users or by making them last longer. This paper considers the second of these options. It does so by examining car use in the UK. This sector has been chosen as it uses an energy and material intensive product. With 2 million new cars registered in the UK each year (DFT, 2013) the GHG emissions associated with the manufacturing and maintaining of cars accounts for 1.5% of the UK's total annual consumption based GHG emissions (House of Commons Energy and Climate Change Committee, 2012).

The analysis indicates that cars are likely to be scrapped when the owner thinks that the investment necessary to maintain and repair them may not be reflected in their market value. A long term leasing model is proposed as a way of revaluing old cars that will make it more likely for them to remain in service for longer.

How long do cars last

Cars change owners around 4 times during their life (Cooke, 2013). Consequently most new car buyers have little interest in the length of time that the car is designed to last for so it is not included in sales literature. Car lives taken form Life Cycle Assessment (LCA) reports vary widely from for 150,000 to 310,000 km (Schweimer, 2000; MacLean, 2003; Wang, 2012). The Department for Transport (DFT) published the odometer readings for a sample of cars that pass their MOT test (UK's statutory roadworthiness test for vehicles over 3 years old) in 2012 (DFT, 2013). The sample size gives an indication of the number of cars that are still in use. It has been adjusted to take into account the differences in the number of cars registered each year and is plotted along with the median, first and ninth decile odometer reading for distance travelled by the cars in Figure 1. Figure 1 shows no sign of an inherent age cut off on vehicle life. The median and ninth decile figures increase linearly with age up to 8 years when they then appear to plateau with the ninth decile approaches 280,000 km. So it appears that cars have a potential life of 280,000 km. The plateau in the median curve is consistent with higher millage cars being scrapped. The drop off in the sample size for older cars supports this theory.

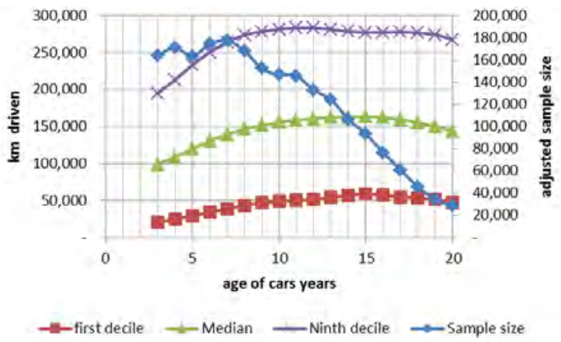

Figure 1. Distance travelled by cars when tested for MOT certificate.

The Automobile Association (AA) estimates that private cars in the UK cover an average of 14,800 km/year so cars should last an average of 19 years if they were all driven for their operational life.

The DFT publish data on the numbers of cars that are registered for use on the roads by year of registration (DFT, 2013). This has been used to calculate the fraction of cars produced in a given year that are still in use which is shown in Figure 2. The percentage in use curve shows that 50% of cars are no longer taxed for use on the roads when they are 13 years old.

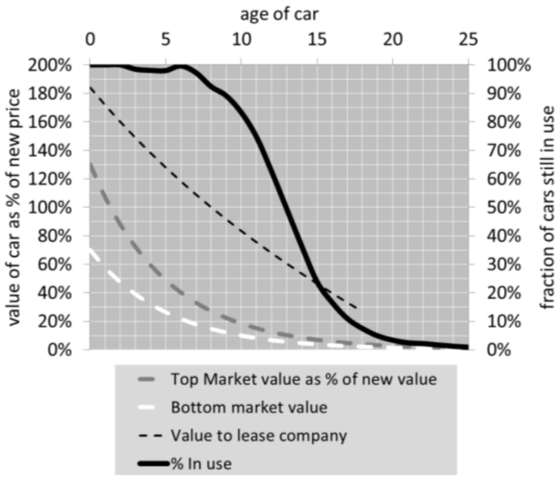

Figure 2. Service life of UK cars.

The other curves on Figure 2 are the upper and lower market values of an average car expressed as a percentage of its new list price. This was produced by generating depreciation curves for eight car models shown in Table 1, using dealers asking prices from the online multi dealer car sales web sites "auto trader" (http://www.autotrader.co.uk) and "carpages" (www.carpages.co.uk).

model	exponent	R2	average annual mileage
Golf	-0.184	0.939	8135
Beetle	-0.188	0.937	7995
Fabia	-0.175	0.919	6812
BMW 3	-0.207	0.899	9401
Mercedes E	-0.215	0.919	11465
Mondeo	-0.223	0.909	13878
Focus	-0.181	0.926	8558
Rio	-0.192	0.833	7587
average	-0.196		9229

Table 1. Car price depreciation.

A geographic search radius was set so that around 70 cars of each model were included in the data. These prices were used to produce depreciation curves for each model. Dealer asking prices were used as these are likely to be consistent. However, the actual sales price is likely to be lower as will the price that an owner could sell the car for. The impact of this error is reduced by normalising the data with the dealers' new car asking price. It was found that all models depreciate at an exponential rate with the values given in Table 1. It was noticed that for asking prices varied by up to ± 30% of the value given by the depreciation curve. This variation was not strongly correlated with car millage so it was concluded that the variation reflected the condition of the car and any accessories fitted to it. The top and bottom market price curves were generated using the average depreciation rate with a ± 30% price range.

From Figure 2, 80% of cars are still in service when the bottom market price approaches 10% of the new car price but only 20% are in service when their top price falls below 10%. It may be argued that as cars get older they become less reliable and this is why owners scrap them. However if this was the case it should be reflected in the cost of break down insurance. Although some providers do have car age limits on their policies, both the AA and RAC offer breakdown insurance that are not dependent on the cars age. Consequently it can be concluded that older cars need not be significantly less reliable than newer ones. It would appear from this that owners scrap cars rather than investing in repairing them when their market value drops below 10%. Therefore one option to increasing the life of a car is to reduce its depreciation rates.

Depreciation in the used car market is a complex topic (Engers, 2009; Gilmore, 2013) and it cannot be changed by decree. But it is possible to value cars for the service they provided. If the car was owned by a business who charged for its use it could be valued as an income generator as well as an asset.

Life long leasing model

Existing car leasing schemes are designed to allow drivers access to new cars without having to pay for them up front. As such they are used by manufacturers to increase sales. These schemes typically last around 3 years with the ex-lease cars being sold on the open market (Andrikopoulos, 2014; Lamar, 2012). This injection of cars into the second-hand market could accelerate depreciation.

An alternative approach is for a company to lease a car out on a series of leases over its life. A basic financial feasibility check has been conducted by comparing the non-fuel cost on a Net Present Value basis (NPV) to the owners of a typical car and the similar cost that they may experience by leasing a car instead. The NPVs are then annualized to take into account the different car life and compared. A discount factor of 3.5% was used to be consistent with UK government project appraisal criteria (H M Treasury,2008).

Assumptions common to both models

Loans are subject to a competitive interest rate of 4.9% (taken from financial services comparison web site http://www.money.co.uk/loans/car-loans.htm).

The annual non-fuel and non-finance running cost for a £20,000 petrol car covering an average distance of 14,850 km a year were taken from AA(2014).

Assumptions for multiple owner case

It was assumed that the car changed hands every 3 years in line with common practice (Cooke, 2013). The first three owners paid a 33% deposit and financed the rest of their purchase by 3 year loans. The 4th and 5th owners paid cash for the car.

At the end of their three year ownership period each owner part exchanges the car for 70% of the dealers selling list price as suggested on an insurance web site, (http://www.churchill.com/car-insurance/tips/car-part-exchange). The car is scrapped after 14 years at no cost to the owner in compliance with the vehicle end of life directive (DFT, 2005).

Assumptions for Life-long lease case

The company would buy the car with a 100% loan paid back over 6 years. A fixed target annual service fee was added to each year's cost.

The current UK tax law allows the asset value of low emission cars to be fully depreciated in one year, other cars are depreciated at 8% a year (HMG, 2014). Consequently the car is depreciated at 8% a year. The value of the future fees are added to the asset value of the car to produce the total value of the car to the lease company.

It was assumed that keeping a car for more than 14 years would incur some additional repair costs. An additional allowance of £500/ year has been added to the annual cost for cars over 14 years old (based on reported maintenance cost taken from the consumer web site (http://www.whatprice.co.uk/ car/price.html).

Financial results
The annualized NPV for the multiple owner case was found to be 14.8% of new purchase price a year over the 14 year car life. It was found that the lease company fee could be as high as 4.43% of new purchase price per year to produce the same annualized NPV for the client. This gives a maximum total fee NPV of 62% over the 18 year life of the vehicle.

Advantages for the driver
The driver enjoys the following advantages:

- no need to find cash deposits
- maintenance and repairs are paid for
- no risk of being without the use of a car.

Advantages for the industry
The globalized car industry has concentrated production in a few capital intensive facilities. It operates with EBIT (earnings before interest and taxes) to sales margins of 6-10%) (Statista, 2013). This profitability is dependent on maintaining high sales volumes. These are subject to factors outside of the control of the manufacturers like interest rates and taxation. To reduce external risk manufacturers are increasingly refocusing their activities into selling services rather than goods (Deloitte Research, 2006; Visnjic; 2011; Foresight, 2013). This servitization of business gives a company a continuing relationship with their customers, smoother cash flows and frequently less exposure to external risk (as more of the value added activities are internal to the company). The multi lease models described in this paper offers servitization options for alliances between the manufacturer, financial service and servicing agents to work together in a new business model that could potentially reduce cost and increase profits whilst offering a lower cost option to their customers.

By extending the life of cars the growing demands for use of cars can be met without the need for a proportional increase in production facilities. This would reduce the need for considerable investment in new production plants.

Environmental consideration
It has been argued that there may be an environmental advantage in shortening a product's life (Intlekofer, 2010) so that it would be replaced by a more efficient model. However from the experience of car scrappage schemes this only happens where the replacement vehicle has very low emissions (Brand, 2013; Kagawa, 2013). Emissions associated with a car can be split into embodied emissions (those associated with its manufacture and primary material production) and operational (those associated with driving it). Both need to be considered when evaluating the consequences of increasing a car's life on emissions (van Nes, 2006).

The key question is how far do you have to drive a new car in a year before the emissions savings achieved by driving it rather than an old one are more than the annualized embodied emissions of the new car.

LCA studies show that the major source of GHG emissions is the production of primary materials, consequently the GHG embodied per tonne of car should be used to compare the findings of the studies. The results from 3 LCA studies of cars are given in Table 2. They show a gradual improvements in embodied emissions over time.

study	model	tCO_{2e}	tCO_{2e}/t_{car}
Schweimer (2000)	VW Golf mk4	6.8	6.8
MacLean (2003)	Ford Taurus	10.0	6.6
Wang (2012)	generic petrol	7.3	5.4

Table 2. Embodied GHG emissions from LCA studies

The latest of the studies (Wang, 2012) give the embodied GHG emission in a 1.3 t car as 7.3 tCO_{2e} which could be annualized as 0.52 tCO_{2e}/y over 14 years.

Emission rates vary considerably between models so the environmental consequences of driving a car for longer or replacing it will be case specific. For example the difference in emission rates between an entry level MK4 and MK7 petrol VW Golf is 45 gCO_2/km (http://www.carfolio.com/specifications/models/car/?car=81169).

Consequently if a 14 year old MK4 Golf was driven for more than 11,000 km/year it would be possible to reduce GHG emissions by replacing it with a new MK7 one. This is close to the average millage covered by a privately owned petrol car in the UK of 10,700 km (DFT, 2014). A report into UK car usage (Lucas, 2009) indicates that significant demographic groups are likely to drive less than 11,000 km/yr. Consequently there are groups of motorists who could reduce their car's total GHG emissions by driving them for longer.

GHG emissions are not the only emissions that cause environmental concerns. A LCA study for a Mk 4 VW golf (Schweimer, 2000) show that 75% of particulates, 50% of SO_2 and 40% of NO_2 life time emissions to air and 70% of all emissions to water arise from primary material production and vehicle manufacture. Consequently keeping a car for longer reduces the annualised value of these emissions.

Conclusions

It has been shown that in the UK, cars appear to have an inherent operational life around 280,000 km, but many are scrapped before this as their market value falls below 10% of their new price.

A lease company that adopted a strategy of leasing a car for its full operational life would consider the car as a source of future profits in addition to its asset value. This would make it economically viable for the company to repair an old car rather than scrap it. As a consequence cars would be driven for 18 years rather than an average of 13 years, a life extension of 38%.

Cars in the UK are typically sold 3 to 4 times during their life. This means that a car is likely to be subject to a number of finance deals and part exchange agreements. The lifetime cost of this multiple owner pattern has been compared to the cost for sequential leasing over a longer life and it was found that sequential leasing could be financially attractive to drivers and leasing companies.

It was thought that if car manufacturers and service agents were partners in the leasing company there could be further reduction in costs.

The environmental consequences of using a car for its full operational life was considered and it was found that this would be beneficial for cars that are driven less than the average mileage year.

Acknowledgments

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"Worker, build your own machinery!" A workshop to practice 'technological disobedience'

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Keywords: repair; DIY; Cuba; product design; technological disobedience.

Abstract: This paper presents an account of the experience of a workshop with the title "Worker, build your own machinery!", held at Politecnico di Milano. The title of the workshop refers to an Ernesto Che Guevara's quote in a 1961 speech: as the Republic of Cuba's Minister of Industry, his aim was encouraging Cuban workers and technicians to face the scarcity of resources due to the country's economic and political crisis. The general approach he suggested to address this issue was self-production of the spare parts required for productive activities: this would involve a number of strategies, such as repair, reuse and repurpose. Self-production included a drive towards the re-appropriation of technologies, suitably combining mass-production and handicraft tools. Over time, these practices became common not only in the field of industrial production, but also in everyday life. This workshop was directly inspired by the research work of Ernesto Oroza, designer and Cuban artist, who studied the changes that 50 years of isolation produced on the island's materiality. The first part of the paper introduces and explains the theoretical concepts on which the workshop was based, whereas the second part exposes and discusses the resulting outcomes. This will include a reflection over the role of design and designers facing the deep social, economic and technological changes we are currently experiencing. These considerations will be aimed at encouraging future designers, emphasising the importance of their educational role and providing inspiration regarding issues, such as repair, reuse and repurpose, which are all essential for a sustainable approach.

Introduction

The aim of the paper is to describe the workshop experience that was held at the School of Design of Politecnico di Milano which focused on the topics of repair, reuse and repurpose in the context of product design.

In present society, discussion about repair, reuse and repurpose activities and DIY practices is exciting, not only because these are key strategies to improve design sustainability but also in that they enable people to express themselves and find personal satisfaction (Salvia, 2013). We need to be aware that we are living through a new industrial revolution (Marsh, 2013; Anderson, 2011), that is based upon the merging of craft and industrial methods. Thus reversing the trend that led, in the last century, to a shift from local to globalised production and therefore permitted the return to individualised practices (Tanenbaum et al., 2013). This revolution is possible thanks to the democratisation of technological practices and product design (Tanenbaum et al., 2013; Von Hippel & Paradiso, 2008) that enables people to come back to the pleasure of craft and DIY activities (Salvia, 2013). Some scholars also called this pleasure haptic satisfaction (Rosner & Bean, 2009). Nowadays, personal fabrication of a majority of objects is accessible to everybody as a result of new modes of production, which were in the past only available to large organisations (Mota, 2011). The user is no longer just a passive consumer, lost in the loop of compulsive consumption, but is allowed to become a creative appropriator, a hacker, a tinker and even a co-designer (Tanenbaum et al., 2013). In literature, a considerable amount of research focuses on the users' modification of mass-produced goods, defined e.g., as *Design by Use* (Brandes et al., 2008), *Non intentional Design* (Brandes & Erlhoff, 2006), *Objects in Flux* (Mitchell, 2011), only to name a few of these strategies. The practices of object modification, appropriation, misuse and re-use present a long and diverse history. We can state that such actions are an integral part of our engagement in the world and are therefore not at all extraordinary. However, when faced with the normalised and highly scripted products of mass-production, these actions take on an unusual and often disruptive quality (Mitchell, 2011). Other research goes beyond the above, rather emphasising the dimension of the interaction in the practice of appropriation and transformation of daily objects. These practices are grouped in the expression of Everyday Design (Wakkary & Maestri, 2007; Wakkary & Tanenbaum, 2009; Wakkary & Maestri, 2011; Desjardins & Wakkary, 2013) and are based on the fact that people creatively and constantly appropriate and transform objects around them. Non-expert designers are able to customise, reuse, repair, appropriate artefacts with a DIY approach and today supported by these technologies of tinker-maker revolution. Connected to Everyday design in fact, there is the concept of Everyday Making (Shewbridge, 2014) that describes the process of creating physical representations of ideas using fabrication tools. The scholars analysed the 3D printer as a tool for Everyday Making. This research proves that nowadays people are motivated to use a 3D printer at home for different purposes: replacing objects that were broken or missing, duplicating objects or making small alterations to existing objects.

3D printing and DIY

In our developed society, we are looking for new ways for producing goods. We are witnessing the diffusion of additive manufacturing technologies, including FDM (Fused Deposition Modelling), one of the most widespread techniques used for 3D printing models, prototypes or products. Thanks to 3D printing it is possible to open up and explore the convergence of virtual and physical words and offer people powerful new tools of design and production (Lipson & Kurman, 2013).

In fact, similar to the advent of desktop publishing, today’s emerging digital manufacturing technologies are opening up a potentially world-changing approach to entrepreneurship: the World Wide Web allows sharing, modifying, personalizing, hacking, etc., almost anything. Fox (2014) called this phenomenon a Third Wave DIY to identify a “DIY that draws upon the read/write functionality of the Internet, and digitally-driven design manufacture, to enable ordinary people to invent, design, make, and/or sell goods that they think of themselves”.

As a result, everyone can be a designer, hence capable and motivated to modify, appropriate,personalize, repair, reuse and repurpose designed objects and systems: however, the reasons behind these activities can be varied and different (Maestri & Wakkary, 2011; www.designforrepurposing.com). As a matter of fact, such practices can often be found in situations where social, economic, or material constraints limit the availability of goods and services; so that people are almost obliged to redesign their life and the objects that give shape and sense to it. The lack of availability for products is perceived like a marketplace evaluation that can motivate DIY behaviour, thus encouraging people to perform DIY activities for goods, repairs, and maintenance (Wolf & McQuitty, 2011).

In this paper, we present the workshop on the repair, reuse and repurpose in product design. This workshop was directly inspired by the research work of Ernesto Oroza (www.ernestooroza.com), Cuban designer and artist, who studied the changes on materiality of the island caused by 50 years of isolation, focusing especially on the last 25 years (Cuba's DIY Inventions from 30 Years of Isolation, available: www.youtube.com/watch?v=v-XS4aueDUg; Oroza & de Bozzi, 2002).

The paper presents the first part of the explanation of the theoretical concepts on which the workshop was built, that it will be explained and illustrated in the second part.

The first part of the paper introduces and explains the theoretical concepts on which the workshop was based, whereas the second part exposes and discusses the obtained outcomes. This will include a reflection over the role of design and designers facing the deep social, economic and technological changes we are presently experiencing. These considerations will be aimed at encouraging future designers, emphasising the importance of their educational role and providing inspiration regarding issues, such as repair, reuse and repurpose, which are all essential for a sustainable approach.

Cuba: DIY society

The history of Cuba is not very different from that of other Caribbean islands. A succession of conquerors has resulted in very unstable economic and political situations that have lasted centuries, and, have influenced the development of the island. What makes this history very different are the facts, which took place, starting around the mid twentieth century, when Cuba became an outpost of resistance against the North American domination. Thanks to the help of the Soviet Union and the decision to direct the young revolutionary government towards communism, Fidel Castro influenced the destiny of the island and Cuban people.

After the U.S. left Cuba back in the 60's, when the embargo was declared, they took with them most of the engineers too. So Ernesto Che Guevara (Cuban Minister of Industries at that time, 1961-1966) told the citizens to learn how to make stuff themselves. “Obrero construye tu maquinaria!” (i.e. “Worker, build your own machinery!”) was the exhortation that Guevara launched to the participants of the First National Reunion of Production. This event was the first ideological impetus to the National Cubans Movement of Innovators and Inventors. They were called the National Association of Innovators and Rationalisers (ANIR), and innovating and rationalising was exactly what they did. This was the beginning of Cuba's backyard innovation.

Figure 1. Dr Ernesto Guevara speech, Industry Minister in the Production National Meeting in 1961. Source: © Ernesto Oroza.

Ernesto Che Guevara's exhortation was chosen as the title of our workshop in a provocative way to encourage students to take action in innovating design, starting from fabricating their own tools. We think that this exhortation is very up-to-date in the context of design that we described before.

At that time, Cubans had no choice but to create and repair, over and over again, both the state factory machines and the smaller machines in their homes: fabricating goods not officially available on the island became an essential skill.

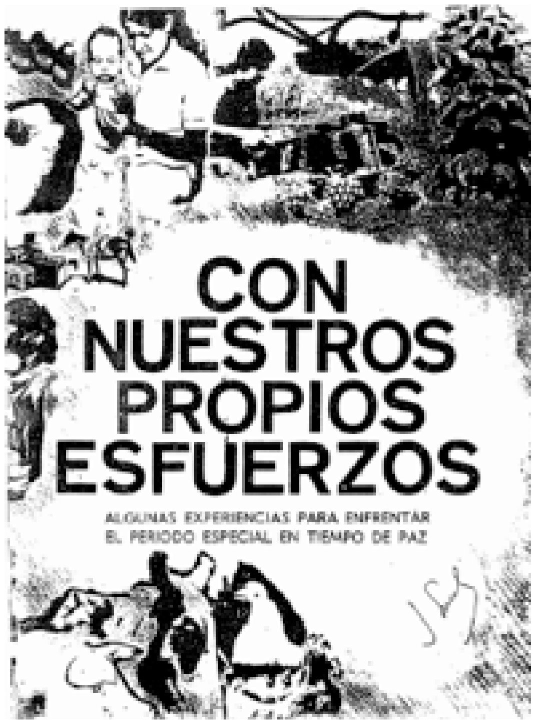

Figure 2. In 1992, The Cuban military issued a book called “Con Nuestros Propios Esfuerzos” (With Our Own Efforts) that detailed crowd-sourced ideas on manipulating, repairing or reusing everyday objects. Source: © Ernesto Oroza.

This first wave of makers left a trail of invention that changed the course of interacting with technology in Cuba (Oroza, 2009).

The second wave that definitively converted the Cuban society to a DIY society, started when the Soviet Union collapsed (1991) bringing to an end the USSR's aids to this small island. In 1991 the Cuban government proclaimed a “Special Period” of extreme rationing and shortages. In 1993, a desperate new law finally permitted, despite some restrictions, the start of businesses dedicated to making and tinkering. A new era of creative enterprise was forced open (Oroza, 2009). The lack of goods, rather than money, shaped Cuban attitudes towards objects (Oroza, 2012; Hill, 2011).

During the Special Period, started in 1991, and with an end not declared, Cuban people realised that in retrospect goods in previous decades had been plentiful, and they began working on and with these objects. For a long period nothing new came to the island, and used objects provided the only material for creating new objects (Oroza, 2012). The components of broken and unusable objects became vital and necessary components for other objects. Nothing was thrown away: in contrast, everything was kept, since it could become precious and valuable in the near future.

Cubans began to bring this repair mind-set home, turning their own households into laboratories. The Cuban home became a laboratory of invention and survival (Oroza, 2009) and at the same time it effectively eliminated litter as a problem.

The Technological Disobedience

The Cuban artist and designer Ernesto Oroza coined the expression 'technological disobedience' for defining everyday creative practices raised in Cuba in the 90's. Oroza defines 'technological disobedience' as the Cuban's systematic disrespect towards complexity, closeness and the exclusionary characteristics of industrial objects and their logics.

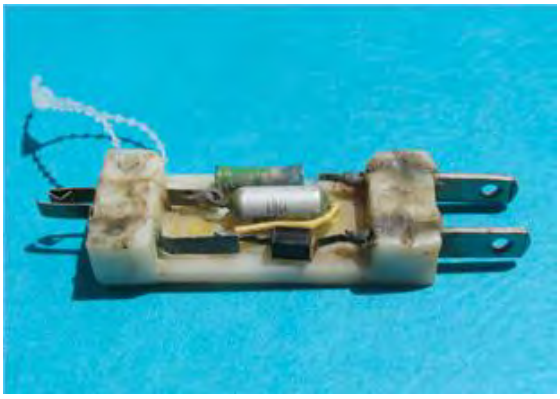

Figure 3. Battery Charger for battery non-rechargeable (two capacitor, one diode), 2007. Source: © Ernesto Oroza

The greatest majority of industrial objects are closed, complete and nearly airtight, while their design may explicitly exclude the possibility of the user repairing or intervening upon them. From his studies and collections (Oroza, 2002; Oroza, 2009), we realise that Cuban people weren't discouraged by complexity or scale: moreover, they learned to disrespect the 'authority' of any kind of objects. They weren't afraid to rethink the objects' original purpose and life cycle, as the most expert professional designer.

The watchwords were 'resolver' (to solve in English) and 'inventor' (to invent but also to dream up), and with these aims the Cuban industrial culture dissected, opened all possible bodies, repaired and altered all kinds of objects, undeterred by their technical complexity and scale, such as automobiles.

As a surgeon becomes desensitised to wounds, Cubans became desensitised to designed objects. They stopped seeing the original purpose of the object, instead thinking of it as a collection of parts. This is the first Cuban expression of disobedience in their relationship with objects, a growing disrespect for an object's identity and for the truth and authority it embodies.

The people of Cuba also invented, designed and produced the tools and machines to create and modify objects that came from the domestic industrial production. Cuban homes became archives, storage places, warehouses, workshops, design studios, production places and shops. They created a completely new market with reinvented industrial products transformed thanks to a craft approach, in a communist country where the concept of market was forbidden.

Figure 4. Recycled plastic objects. Source: © Ernesto Oroza.

It is remarkable that the questioning of objects and of industrial logic came from a craft perspective. They were logical and industrial products reviewed from traditional processes and manual operations. Industrial products started to be tinkered with and examined by hand. The accumulation of products led workers to radically question industrial processes and mechanisms. They started looking at objects with the eyes of an artisan. Every object could potentially be repaired or reused, even in a different context from its original design. The technological disobedience became the most reliable resource for Cubans to navigate the inefficiencies of the state political system.

The workshop: "Worker, build your own machinery!"

This section describes the workshop with Product Design Master students, which was considered as a pilot study. This section also presents findings related to the workshop experience.

Aims

The workshop was developed to introduce product design students to the issues of repair, reuse and repurpose of objects. Instead of directing them immediately to the important subject of sustainability, we chose to emphasise the DIY approach and the use of additive manufacturing technologies such as 3D printing with FDM desktop 3D printers for their easy access. Furthermore, we used the Oroza's concept of Technological Disobedience because we considered it as innovative, exciting and promising. We can say that this is an extreme case of Everyday Design and Making approach that allows students to look at the design process as something that has never actually had an end, but as something that is always in-progress. In addition, this concept permits students to look at objects according to another logic, starting from a different point of view and disobeying their predetermined authority.

Characteristics

The workshop was organised in the Masters of Product Design at the School of Design, Politecnico di Milano on May 2014. Forty students of the second year were involved, including eight foreign students from Colombia, Brazil, Spain and England. The period of the workshop was five days spent together in the classroom: during that period four lectures were delivered and the students researched, worked and designed. The classroom was equipped with large tables for working on different materials with simple handle tools brought directly by the students, while they also had access to the well-equipped workshop of the School and to a provisional 3D printing corner organised by +Lab (www.piulab.it) with four 3D printers desktop FDM.

Tasks

In general, the workshop tried to build a suitable environment for carrying out exercises in repair, reuse and repurpose for motivating an analytical look at the potential and the limits of the artefacts we consume, as we knew from other cultures, needs and approaches. It contributes to research on repair and the DIY approach through design activity. In particular, the tasks of the workshop are undertaken both individually and in groups. The two exercises of the workshop were:

1) *One glass per day*: daily exercise aimed to train each student in the practices of reuse, repurpose and improvisation. Mode of participation: Individual. On each day, the students were asked to develop a drinking vessel in one hour using simple and provisional materials and processes (Figure 5). The task is aimed to drive the participant towards facing a continuous need. This will allow exploring and encouraging ideas of improvisation, re-use, reproduction, appropriation, adaptation and so on. The idea here is to look at the object as something that was never realized before and with the goal to solve ("resolver") a basic need: to drink. The participants considered the raw materials available in their own home and they had to work with simple tools (scissor, cutter, glue…).

2) *Re – exercise*: This was a group project that was carried out throughout one week. The aim was to repair, reuse or repurpose objects to design others objects or machines. We asked the students to bring to the classroom broken or obsolete objects and we gathered them on a big table (Figure 6) in the centre of the classroom.

Figure 5. Students while designing the drinking vessels.

This table was the metaphor of the accumulation process that we described above. We asked the groups (ten groups in total) to find

a basic need (eat, drink, wash, and so on…) and design an artefact or a machine accordingly, using the objects or parts of the objects they brought and shared with the classmates.
They work in their projects using simple and basic tools to transform, change and convert the components from old to new objects, trying to apply the Technological Disobedience approach. Furthermore, in this exercise, the participants were invited to consider the possibility to use the 3D print technology (FDM) to design special components for including them in the final solution (Figure 7).

The use of 3D printing in repair and reuse as well as in product design research has grown in recent years. For example, Martino Gamper's project called "In a State of Repair" (http://martinogamper.com/in-a-state-of-repair/) is a collaboration between the designer and the renowned Italian department store La Rinascente and London's Serpentine Galleries. This project celebrates the craftsmen, craftswomen, artisans and technicians who repair the objects that break down, stop working or go wrong.

Figure 6. Broken or obsolete objects brought by students.

'In a State of Repair' was also launched at the Salone Internazionale del Mobile 2014, to explore the expectations of customer service and the story of consumption; a story that does not necessarily end when a person purchases an object and leaves the store. A small 3D printing lab was used during the faire to create spare parts useful to fix other stuff.

Another recent research involving 3D printing in repair process is the interdisciplinary project 'Making Stories' of the Faculty of Computer Science and the Faculty of Design and Arts, Free University of Bolzano (http://vimeo.com/118686468?from=facebook). 'Making Stories' wanted to extend the lifespan of daily objects, technologies and materials long after their warranty had expired. It is a participatory collaboration between young designers and computer scientists who challenge the short lifespan of daily objects, technologies and materials. They work with broken, apparently useless, things, repairing them or creating new objects, which present alternatives to the current economic model characterized by mass-production and consumption.[1]

Figure 7. The +Lab corner with 3D Printing facilities.

Results and discussion

In this section we illustrate and discuss the results obtained from both exercises of our workshop.

Figure 8. 1000 improvised and provisional drinking vessels.

The first exercise "One glass per day" was useful to train the research of design solutions for a repetitive need. This resulted in the

[1] (http://adhocracy-athens-sgt.tumblr.com/post/108492024552/making-stories-faculty-of-design-and-art-and).

creation of a collection of about 1000 solutions for designing a drinking vessel.

The exercise was very interesting because in a small time the students saw a big number of solutions and projects that they could deal with and also were able to compare them. Furthermore, they experimented with the ease of building a physical model, a sensation with which they are not very accustomed.
To exemplify findings from the second exercise we selected two case studies amongst all the projects: SHOW-er and Termoformastira. We decided to illustrate these two projects because they are good examples of the process that students carried out during the workshop. SHOW-er's outcome was an object and Termoformastira's outcome was a machinery to produce objects.

SHOW-er

From all objects brought, they were given randomly one object to address one basic need: entertainment.

Figure 9. Objects selected by the students of the Group 9 to carry on their task.

The principal object assigned to them was the old-fashioned stereo, which is obsolete in terms of technology and also in terms of its design. However, this stereo was still working. The students themselves firstly selected the other objects randomly and then, after deciding the design solution, they changed some objects with others accordingly to their final idea of the project.

The students thought to work on the concept of obsolescence of the object and decided to upgrade its functions transforming it in a karaoke system able to support mp3. To translate their idea in a concrete product they applied the technological disobedience approach, so that they weren't scared to open the body of the stereo and other objects and operate on them. They didn't use the 3D printer, since this was not compulsory.

Figure 10. Students hacking the circuit to include a microphone (the shower components) and to connect a mp3 player.

The students worked in a group, sharing and comparing ideas, doubts, skills and successes. A video was produced as part of our findings to understand properly the design process, as well as the repair, reuse and repurpose exercises carried out by the students.

Figure 11. The SHOW-er, a karaoke system. (https://vimeo.com/95500867)

Termoformastira

In the same way as described in the previous project, students were given a random object and picked up other objects (Figure 12). The need they addressed was related to a basic human need: drinking. Taking into account the first object we assigned to them, the flat iron, they decided to design a machine to produce glasses using a kind of primitive thermoforming process.

Firstly they fixed the iron and then looked for other objects in the table, coherent with their idea. They decided to use a pneumatic piston removed from a broken seat (Figure 13). They used the 3D printer to produce connection parts in PLA exploiting the fundamental characteristics of this flexible technology that is useful to produce customised components in a small number. The design process, repair, reuse and repurpose exercises were also captured on video (Figure 14).

Figure 12. Objects selected by the students of the Group 2 to carry on their task.

Figure 13. The pneumatic piston as a useful component of this new machinery.

Figure 14. Termoformastira, a domestic thermoforming machine. (https://vimeo.com/95498670)

Dissemination of results

As we can experience, personal initiatives and new uses for tools and materials from around the world are shared through online and offline communities and events (Tanenbaum et al., 2013). To communicate and explain the design process of each group, we asked them to produce a video with step by-step descriptions to facilitate distributed craft knowledge. Sharing would firstly take place inside the workshop, and then also in the worldwide community of people interested in discovering these creative solutions and ideas to extend the life of products.

We created a Facebook page and we published all the videos on YouTube, Vimeo and on Ernesto Oroza's web site.

Conclusions

In this paper we gave an account of our workshop experience focused on repair, reuse and repurpose practices and about the possible contribution that the product design competencies can give to these design activities. Our suggestion to today's product designer is to read the Guevara's exhortation as an invitation to look at production and at the objects in a different manner. This exhortation still sounds a little bit revolutionary today because we are in a historical moment where the well-established discipline of product design is faced with issues such as: DIY, maker, digital manufacturing, open source and so on. Also the repair theme, included its facets of reuse and repurpose, begins today to be taken into account in the field of product design.

It is not just about designing durable and repairable artefacts, the design community strives and challenges also to fix, reuse and repurpose artefacts which have not been designed to be adjusted. The repair process thus becomes a transformation, which encourages us to consider the longevity and the preserving of objects rather than the discarding of them. This enables us to value the intrinsic creativity that is part of the act of buying.

The workshop was developed by trying to put together all these concepts and present them to students of Masters in Product Design with a dual purpose. The first was a didactic one, focusing on raising students' awareness about these current and important issues. The second purpose was focused on practical research, trying to understand from the performance of the exercises and their results which contribution the designer can give to these processes of extensive creativity, Everyday Design, which even ordinary people seem able to master without a specific background in product design disciplines.

Acknowledgments

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Web resources

http://www.ernestooroza.com/
Cuba's DIY Inventions from 30 Years of Isolation: www.youtube.com/watch?v=v-XS4aueDUg
www.designforrepurposing.com
http://cubamaterial.com/

Annexes

Group 1 Video: Fan to fun
http://www.facebook.com/video.php?v=1015209571946724&set=o.251960084989631&type=2&theater

Group 2 Video: Termoformastira
https://vimeo.com/95498670

Group 3 Video: Pesucola
https://vimeo.com/95500233

Group 4 Video: Grill-O
https://vimeo.com/95502355

Group 5 Video: +BBQ
www.youtube.com/watch?v=WB7s5ZvsOKw

Group 6 Video: Trampa para animales molestos
https://vimeo.com/95498339
Group 7 Video: The toast-balino
https://vimeo.com/95500879
Group 8 Video: Just Grow
www.youtube.com/watch?v=IKQ07_oSRow&feature=youtu.be

Group 9 Video: SHOW-er
https://vimeo.com/95500867

Group 10 Video: Dora La Lavadora
https://vimeo.com/95500203

Constructing customer experience for augmenting apparel products' attachment and longevity

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Keywords: product attachment; longevity; customer experience; product-attachment framework; sustainability.

Abstract: Designing longer lifetimes for products is a prerequisite for a sustainable future (Cooper, 2005). In yester years, apparel products had a definite life-span and were used for their entire active life which was even extended through alternative use. In today's times of changing consumer psychology and increasing disposable incomes, consumption has changed its meanings and dimensions. Over consumption has reduced product lifespans, inducing quicker discards and huge disposals. In order to make sustainable development an achievable goal, consumer involvement is essential. Manzini (1994) argues that the actual focus in sustainable development should be on people's consumption behaviour. Mugge et al. (2005) argue that if a consumer feels attachment to some product s/he will handle it with good care, repair it and even postpone its replacement.

Niinimaki and Koskinen (2011) identified the elements of proactive sustainable fashion design and explored person-product relationships. They identified alternative methods in design for sustainability and the impact of sustainable design on clothing consumption and customer satisfaction. The current study aims at identifying attributes of apparel products (besides core design; such as usability, maintenance etc.) and elements of retail interface and service-scape that are instrumental in creating product-attachment and longevity. The study will also explore the role of customer experience in inducing product attachment. Finally, a product attachment framework will be developed by aligning customers' psychology and behaviour patterns through the construction of unique experiences.

Product attachment

Mugge (2007) defines product attachment as the strength of the emotional bond a consumer experiences to a specific product. According to Mugge, Schifferstein and Schoormans (2006), if people feel strongly attached to a product, they are more likely to handle the product with care; to repair it when it damages and put in their best efforts to postpone its replacement as long as possible. Consumers become attached to certain products, because these products convey a personal and special meaning over and above the utilitarian value (Mugge, 2007). Consumers' emotional attachments to products can increase their lifespan (Mugge, Schoormans, and Schifferstein, 2005) and this can prove valuable in the context of environmental damage, caused by premature disposal before the active life of a product has been reached.

Factors influencing product attachment

Various factors related to product features, usage, retailer or brand name, retail environment, service interface, social environment, affect consumers' psychology towards the product. In different studies, researchers have identified four factors that induce product attachment (Richins 1994; Kamptner 1995; Kleine, Kleine, and Allen 1995).

a) Self-expression (Distinguishing oneself from others through the product)
b) Group affiliation (Establishing social connections and obtaining social approval through product ownership)
c) Memories (Unique and lasting remembrances related to the product and its purchase) and
d) Pleasure (Enjoyment obtained during purchase and consumption).

Self-expression relates to endorsement of product through association with product personality which is "the set of characteristics that people use to describe a specific product variant and discriminate it from others" (Govers 2004). It gets manifested through the product's shape, material, colour, texture, retail interface and usage (Govers, Hekkert, and Schoormans 2002; Jordan 2002). Consumers bond strongly with products that have a 'personality' congruent to their own and communicate their individuality through these products (Govers and Mugge 2004). Sporty people get attracted towards Nike products and adventurous people value Patagonia products due to its product personality. Armani enables its customers to flaunt a distinguishable elegance.

Apparel products and concept of attachment

Fashion products, especially apparel, are greatly influenced by evolving concepts, climatic conditions, body measurements, fit aspects etc. (Solomon & Rabolt, 2004). Product attachment and sustainability have difficultly fitting in the fashion world where people indulge in over-consumption and throw-away activities due to psychological and social pressures underlined by changing trends. The challenge is not just to increase the physical lifespan of apparel but also to extend the psychological life. Here consumer approval and acceptance for the aging apparel product is maintained at a considerably high level, and is not decreased by new offerings in the market.

Role of customer experiences in apparel attachment and longevity

Customer experience is the sum of all experiences a customer has with a supplier of goods and services, over the duration of his/her relationship with that supplier (Roebuck, 2012). Customer experience is "the takeaway impression formed by consumer's encounters with products, services, and businesses—a perception produced when humans consolidate sensory information" (Carbone & Haeckel, 1994). It is the key factor for companies to use, in building loyalty to brands, channels and services (Badgett, Boyce & Kleinberger, 2007).

According to Schmitt (1999) customers encounter sensory, emotional, cognitive, behavioural and social experiences during various phases of product purchase and use. These experiences have significant impact on consumers' psychology and behaviour towards the product, and can result in attachment. Product features, store attributes, retail environment and service-scape act as experience determinants. Experience also emerges from the social environment (need of social acceptance, social status, reference group opinion) and from the natural environment (awareness of environmental issues, and customers' psychological and behavioural responses). The study by Gentile et al. (2007) identified the constructs of customer experience as –Sensorial (senses), Emotional (affective system of generation of mood, feelings, emotions), Cognitive (mental processes, problem solving), Pragmatic (practicality, usability), Lifestyle (values, beliefs related to lifestyle & behaviour) and Relational (social context, relationship with other people).

Customer experiences play an important role in developing associations between consumers, products, brand and elements of the retail environment (Verhoef et al., 2009; Puccinelli et al., 2009). When actual experiences match customers' expectations, they are happy and retain memories of product-purchase and product-usage for longer periods. When actual experiences exceed customer expectations, they feel delighted and build stronger associations with the brand or product. Figure 1 gives the customers' experience-attachment relationship.

Figure 1. The experience-attachment relationship.

The below given Table 2 depicts the Customer experience and product-attachment matrix.
Apparel is a form of self-expression and reflects a consumer's lifestyle and personality. Apparel purchase decisions are characterized by a high degree of consumer involvement and depend on various crucial attributes such as look and feel, fit and comfort, relevance to the latest trends, styles etc. and various clues related to the retail store, services etc.

Apparel brands and retailers are interestingly and innovatively using customer experience constructs to explore the different dimensions of experience, and constructing enthralling and intriguing experiences. ModCloth, a trendy, fashion-forward women's apparel retailer creates true social-shopping experience by engaging its customers in business improvement and growth. Burberry, the British luxury brand, introduced an innovative digital strategy to motivate pleasure for consumers. Burberry has partnered with Google to provide its customers with an interactive and visually-immersive experience through its campaign Burberry Kisses. This allows users to send letters sealed with a virtual kiss to friends and loved ones across the globe. Concept stores provide not only great interiors but also, lifestyle experiences to customers. Urban Outfitter, the American multinational clothing corporation, through its concept stores such as "his and hers" and "Space Ninety 8", provides its customers with a completely enthralling shopping experience. This includes different levels of shopping, interaction with local designers, music shops, vintage shops, roof-top dining and so on.

	Experience State	Customer satisfaction state	Product attachment state
Case 1	Actual Experiences < Expected Experiences	Dissatisfaction	Negative
Case 2	Actual Experiences = Expected Experiences	Satisfaction	Neutral
Case 3	Actual Experiences > Expected Experiences	Delight	Positive

Table 1. The experience-attachment matrix.

Objectives

The objectives of the study are:

1. To identify the attributes that creates attachment to apparel products and increase product longevity
2. To identify the constructs of customer experiences acquired through product use, retail environment and service interface, that induce apparel product attachment
3. To develop a product-attachment framework for developing long-term product relationships by constructing experiences.

Factors		Specific attributes used in consumer survey
1. Apparel Product	1	Unique and distinct features (Customized, eco-friendly)
	2	Quality (fabric, color)
	3	Excellent fit, finish and feel
	4	Valuable due to high-price
	5	Timeless and classy style
	6	Easy use and maintenance
2. Store / Brand	7	Purchased from a reputed brand or store
	8	Excellent store experience and memories (ambience, location, display, entertainment)
	9	Excellent information about product features and use provided by store staff
	10	Services provided by store staff in maintaining the clothes
	11	Interesting suggestions by store staff for reuse and renewal of clothes
	12	Eco-friendly practices of the store
3. Consumer	13	Consumer involvement in product design
	14	Gifted by someone dear / special
	15	Made or bought for a special occasion (Wedding, birthday, other special occasions)
	16	Fondness for the endorser / model
4. Social	17	Social acceptance, approval & appreciation
	18	Feeling of looking confident and presentable
5. Innovation for reuse / Environmental sustainability	19	Possibility of product reuse (alternate use) and renewal (refurbishment)
	20	Possibility of delayed disposal as a concern towards environmental damage

Table 2. Customer experience & product-attachment attributes identified from literature review.

Methodology

An empirical study was undertaken. Attributes creating attachment and longevity for apparel products and the related customer experience constructs were identified through a consumer survey. Respondents were in the age group 15-60 years. Data collected from structured questionnaires was analysed using SPSS. The aim was to identify constructs of product attachment that emerge from attributes of apparel products, retailing and associated services that generate positive customer experiences using Factor Analysis.
From an extensive review of extant literature, elements that could possibly induce apparel

product-attachment were identified. Table 2 provides the customer experience & product attachment attributes that were used in the survey.
Factor analysis was done to find out significant factors and experience determinants that affect customers' attachment to apparel products and which may motivate them to use the apparel products for a longer time.

Results of factor analysis

Initially Factor Analysis was performed in SPSS using the Principal Component Approach with a Varimax rotation. The result of Bartlett's test of Sphericity (0.00) and KMO (0.813 > 0.5) indicated that data was appropriate for factor analysis. Using principal component analysis, twenty items were extracted by five factors. Only the factors having Eigen value greater than one were considered significant; others were discarded. All the five factors together accounted for 67.520 percent of the total variance. However through Rotated Component Matrix it was observed that three items were cross-loading in the matrix. These items were the "possibility of delayed disposal as a concern towards environmental damage" with loading value of 0.554 in factor one and 0.618 in factor two, "store staff services for product maintenance" with loading value of 0.675 in factor one and 0.500 in factor two and "store staff suggestions for product reuse and renewal" with loading value of 0.525 in factor one and 0.526 in factor two. Cross-loadings depicted 'insignificance', hence, these three items were deleted from the variable list and final round of analysis was performed.

In the final round of analysis, results of Bartlett's test of Sphericity (0.00) and KMO (0.741 > 0.5) indicated that data are appropriate for factor analysis. Using principal component analysis, seventeen items were extracted by four factors. However items named "possibility of reuse and refurbishing" did not have any value, indicating that respondents' did not express any opinion. Factors with Eigen value less than one were discarded. All the four factors together accounted for 62.458 percent of the total variance. Items having factor loading more than 0.5 were included in the interpretation. Tables 3, 4 and 5 summarize the Factor Analysis results.

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.741
Bartlett's Test of Sphericity	Approx. Chi-Square	1322.305
	df	136
	Sig.	.000

Table 3. KMO and Bartlett's Test.

Total Variance Explained									
Com-ponent	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	5.301	31.182	31.182	5.301	31.182	31.182	3.860	22.707	22.707
2	2.389	14.052	45.234	2.389	14.052	45.234	2.950	17.353	40.060
3	1.759	10.347	55.581	1.759	10.347	55.581	1.956	11.507	51.567
4	1.169	6.877	62.458	1.169	6.877	62.458	1.852	10.892	62.458
5	.986	5.802	68.260						
6	.841	4.948	73.208						
7	.818	4.813	78.021						
8	.681	4.008	82.029						
9	.660	3.880	85.909						
10	.496	2.920	88.829						
11	.462	2.717	91.547						
12	.327	1.925	93.472						
13	.313	1.843	95.315						
14	.248	1.458	96.773						
15	.221	1.299	98.073						
16	.196	1.151	99.223						
17	.132	.777	100.000						
Extraction Method: Principal Component Analysis.									

Table 4. Total Variance explained.

Rotated Component Matrix[a]				
	Component			
	1	2	3	4
Unique & distinct features		.740		
Quality		.654		
Fit, Finish & Feel		.583		
High-priced			.582	
Timeless & Classy style		.698		
Easy use & maintenance		.604		
Consumers' ideas in design		.591		
Gifted by someone special			.884	
Made or bought for special occasion			.806	
Fondness for endorser or model	.654			
Social appreciation				.744
Feeling of confidence and present-ability				.781
Possibility of Reuse and Refurbishing				
Purchased from reputed brand or store	.754			
Store experience & memories	.801			
Eco-friendly practices of the store	.830			
Store-staff information for product use	.891			
Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.				
a. Rotation converged in 6 iterations.				

Table 5. Rotated Component Matrix.

Findings

Identification of attributes that create attachment to apparel products

From Factor Analysis Product factors, Store /Brand factors, Consumer factors and Social factors emerged as most significant in explaining apparel product attachment and thus motivating customers to use the apparel products for a longer period of time. Table 6 depicts the reduced factors. It emerged from the study that the listed factors impact

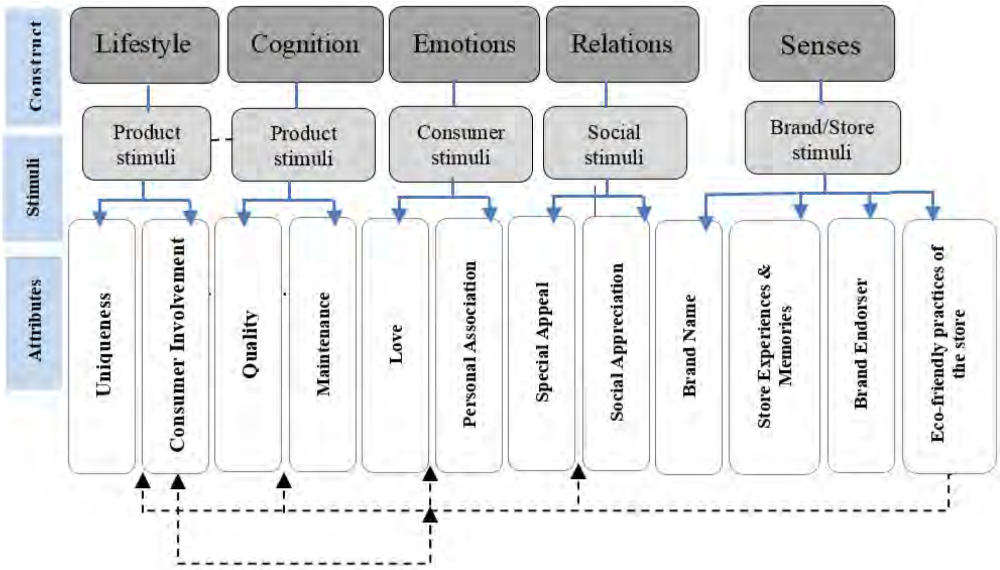

Figure 2. The Attribute-Experience construct mapping.

customers' experiences, attachment with apparel products and product longevity. For each factor, the significant attributes are arranged in order of consumer preference (starting with the most important attribute).

Store or Brand Attributes	- Reputed brand name or store - Excellent store experience and memories - Excellent information about product features and use provided by store staff - Fondness for the brand endorser - Eco-friendly practices of the store
Product Attributes	- Unique and distinct features - Timeless and classy style - Quality - Easy use and maintenance - Consumer involvement in product design - Excellent fit, finish and feel
Social Attributes	- Feeling of a confident and present-ability - Social acceptance and appreciation
Consumer Attributes	- Gifted by someone special - Made or bought for special occasion

Table 6. Factors significant factors for customers' experiences, product attachment and longevity (arranged in order of most important to lesser important attributes).

Identification of customer experience constructs that induce apparel product attachment

Experience dimensions impact consumers psychology by generating related values (lifestyles, cognitive, emotional, relational, pragmatic and sensorial) (Gentile et al., 2007) which have behavioural implications (re-purchase intention, increased frequency of purchase, product attachment, positive word-of-mouth, advocacy).

The attributes obtained from Factor Analysis were mapped with the experience constructs which represent the different dimensions of customer experiences (Gentile et al., 2007). An adapted version of Attribute-Value Mapping (a Systematic Inventive Thinking method, adopted from Genrich Altshuller's TRIZ) was used to map the significant attributes to the causal stimuli which further traced the respective experience dimension or construct responsible for its behaviour.

Figure 2 shows the Attribute-Experience construct mapping. The experience constructs that emerged relevant for attachment to apparel products are:

1) Lifestyle
2) Cognition
3) Emotions
4) Relations and
5) Senses.

The dashed lines shows relevance to more than one construct. For instance, the product attributes are mapped to Product stimuli. However, attributes of 'Uniqueness' & 'Consumer involvement' show more relevance to Lifestyle construct, whereas 'Quality' and 'Maintenance' signify cognitive association. 'Consumer involvement', at the same time has emotional relevance, also. Similarly consumers'

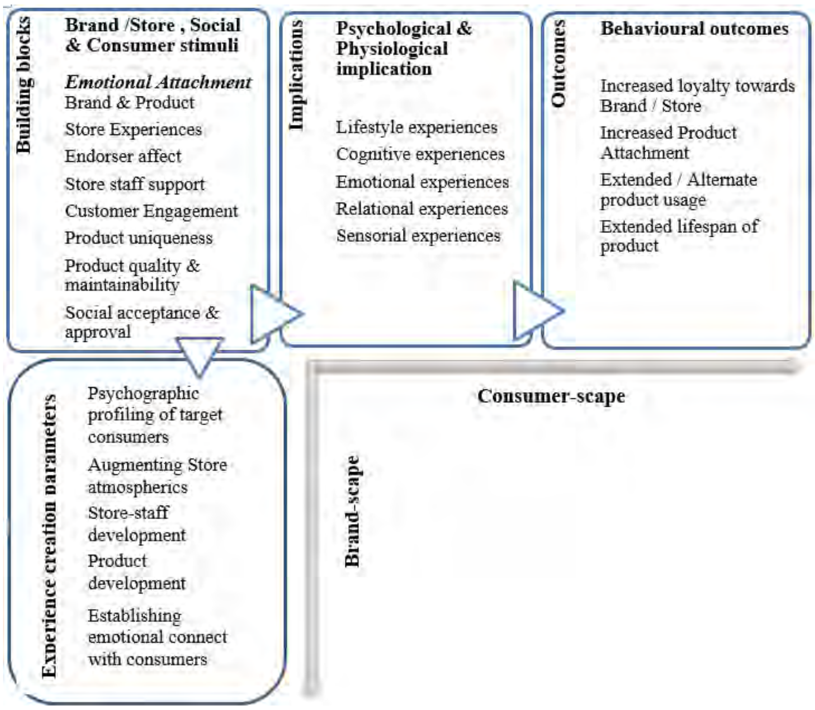

Figure 3. Product-attachment framework.

approval of 'Eco-friendly practices of the store' relates to lifestyle, cognition, emotions and relations constructs in addition to sensorial constructs

Proposed product-attachment framework
The proposed product-attachment framework is based on the mapping of significant attributes that create consumer-product attachment and the experience constructs that contribute in development of long-term product relationships by formulating experiences. Figure 3 depicts the Product-Attachment framework. The consumer-scape is arranged horizontally and brand-scape is presented vertically. It highlights the building blocks of customer experiences that can induce product attachment, the psychological and physiological implications of experiences and the consequent behavioural outcomes. The experience creation parameters for the brands are also proposed.

Conclusions
It can be concluded that the apparel consumers and the fashion-conscious are ready to compromise with protecting the environment, but not with the aesthetics, tastes, styles, design and concepts of uniqueness and newness related to apparel products. They are ready to discard the apparel product irrespective of the fact that it is costly or cheaper, even if there exists several methods to preserve it, or it is in good condition and can also be renewed or refurbished. However, there is more likelihood of retaining and reusing the apparel if it was designed as per their choice or it is especially gifted or was bought for special occasions. The limited concern for sustainability is shown by the respondents' appreciation for eco-friendly apparel retail outlets. It can be inferred that the majority of apparel consumers in all age-groups are more "fashion conscious" and less "environment conscious".

In addition, their apparel consumption is affected by emotions, lifestyle and social environment. Cognitive and sensory experiences also play significant roles in apparel consuming decisions.

Apparel brands are innovatively orchestrating mesmerizing experiences for their customers. But in order to induce product-attachment with a sustainability concern, it is important for brands to converge the different experiences that they provide to their consumers to a focal point of environment ownership and restitution. Sustainability concern needs to be woven into the company's communication, offerings and its touch-points in such an integrated manner that consumers subconsciously start learning a more responsible approach of apparel consumption and move towards 'Fashioning with Sensitivity'.

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What is broken? Expected lifetime, perception of brokenness and attitude towards maintenance and repair

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Keywords: brokenness; vacuum cleaners; maintenance; repair.

Abstract: This paper addresses the discrepancy between the expected and actual lifetimes of vacuum cleaners considering perceived 'brokenness' as a driver for replacement. Among electrical products, vacuum cleaners have a high rate of domestic ownership in the UK. They also embody large quantities of greenhouse gases which could be reduced by increasing their longevity and resource efficiency (Schreiber et al., 2012). A focus on energy efficiency has only shown limited or even negative results, therefore to meet recent European Union regulations on durability requirements a focus on product longevity is needed. Around one half of new vacuum cleaner purchasers replace one less than 5 years old, below the expected lifespan, with perceived breakage, poor performance and unreliability as the major reasons for replacement. Their relative simplicity could allow vacuum cleaners to last for significantly longer. The nature of the common causes of failure is known, including stretched cords or blockages, and WRAP has developed guidelines for product improvements. However, many working or repairable machines are disposed of because they are perceived to be 'irremediably' broken.

This paper explores the drivers of perceived brokenness through empirical work that suggested a loss of suction influences replacement decisions. Suction is closely connected to the machine's condition. Regular, minor maintenance preserves suction power for longer but users appear to neglect it, even finding it irritating (Electrolux 2013). Users' lack of interest in maintenance is a major barrier to prolonging the machines' lifespans, and aligns with their view of vacuum cleaners as 'mechanical servants' offering easy, effortless cleaning (Jackson 1992). However, when a tool breaks down or loses efficiency it suddenly demands attention. The paper addresses possible (and concurrent) factors determining 'brokenness' and the mental calculation of the effort required to rectify it, such as perceived difficulty and the cost of replacement or repair. Using Latour's concept of delegation, it proposes a biological analogy for the relationship between user and machine to establish that brokenness is not necessarily an intrinsic condition but, rather, a perception of the machine demanding unwanted effort of the user.

Introduction

Every year around two million tonnes of electric and electronic equipment (EEE) are discarded by householders and companies in the UK. Vacuum cleaners account for the second largest embodied greenhouse gas emissions of electrical products after televisions, largely due to high sales volumes (Product Sustainability Forum, 2012) and widespread ownership: 87% of the UK population own at least one (MINTEL, 2010).

Two potential areas for reducing the environmental impact of EEE have been set: increased product longevity and resource efficiency (Schreiber et al., 2012). A past focus on resource - and especially energy - efficiency has shown limited or even negative results, the latter due to the rebound effect (e.g. Hertwich, 2005). Arguably the focus on product longevity may generate a more positive impact.

The longevity of vacuum cleaners also deserves further investigation on the basis of the gap between their actual lifespan and the one expected by users. In the three years prior to November 2012, 44% of UK households bought a vacuum cleaner, the second most frequently bought domestic appliance (MINTEL 2013b). According to WRAP (2013), half of vacuum cleaners purchased in 2012 were bought to replace an existing product under 5 years old. However, vacuum cleaners are expected to last for longer, from 5 to 11 years (WRAP, 2013; Brook Lyndhurst, 2011; Which? 2014). Some potential to work with consumers to extend the lifetimes of such 'workhorse products' has been envisaged, with opportunities for several interventions (Brook Lyndhurst 2011).[1]

This paper addresses the discrepancy between expected and actual lifetimes of vacuum cleaners especially in relation to perceived 'brokenness', as a driver for replacement, on the basis of interim findings from a project currently being undertaken by the authors for Defra. In particular, the arguments are based on the results of a survey with 507 vacuum cleaner users across the UK, completed in August 2014.

Replacing because of unreliability

Many people (55-80%) declare that they would only replace vacuum cleaners when they fail or break down, especially during an economic recession (MINTEL, 2010; WRAP 2013). Consistent with this, and despite general satisfaction with the previous model, our survey respondents who had owned a vacuum cleaner previously (n=449) reported that they discarded their vacuum cleaner because it did not work at all or efficiently (44% and 34% respectively). This sustains the hypothesis that the main reason for replacing a vacuum cleaner is related to a machine break down or loss of performance.

Reliability and dust pickup are major considerations when buying a vacuum cleaner (Electrolux, 2013; WRAP, 2013), with price and quality and durability a long way behind (Electrolux, 2013).

Strategies for prolonging product lifespan of faulty items have been investigated and proposed, ranging from manufacturing guidelines for more durable vacuum cleaners (WRAP, 2011a) to more effective warranties (Chukova and Shafiee 2013).

Most notably, a European regulation has recently been introduced, implementing the Framework Directive 2009/125/EC by setting ecodesign requirements specifically for vacuum cleaners and including minimum durability requirements for the motor and the hose (European Commission 2013). From September 2015, operational motor lifetime must be at least 500 hours; considering the testing criteria, it may be inferred that the expectancy of the motor lifetime is around 10 years, thus aiming to at least double current vacuum cleaner lifespans.

Nevertheless, information about the reliability of vacuum cleaners is already available and often easily accessible on the internet. For instance, a Which? report suggests Best Buys ranking vacuum cleaners models on the basis of reliability and consumer satisfaction (Which? 2014); however they do not match the most frequently sold brands (MINTEL 2010).[2]

Furthermore, discarded vacuum cleaners have often been reported to be still in good condition or easily repairable (WRAP 2011b). Therefore other factors, beyond reliability, must determine their premature end-of-life. In the following sections, the relationship between user and vacuum cleaner is explored in order to identify other possible factors for vacuum cleaners having short lifespans, relating to detachment, convenience, commodity and cleanliness.

Detachment from vacuum cleaners and disengagement from maintenance

Vacuuming, and cleaning the house in general, might not be perceived as an enjoyable or engaging task by everyone. In fact, a third of the survey respondents (35%) would like to employ a cleaner but do not for various reasons. It would appear that for UK users the most annoying aspects when using their vacuum cleaner are low suction and noise (Electrolux 2013), and it is unclear to what extent these factors are related.

A recent survey by Which? (2014) identified the most common problems with vacuum cleaners, which included blocked filters and broken belts and brushes in upright models. These factors are mainly related to the attitudes towards proper use and maintenance, according to an interview with a local vacuum cleaner repair specialist.

[1] The term 'workhorse product' is used in Brook Lyndhurst (2011) when referring to products purchased primarily on the basis of their function and expected to do a job reliably.
[2] In a survey by Cooper and Mayers (2000), many respondents (73%) regarded information on expected product life as very important and more than half (54%) were dissatisfied with currently available information. Half of respondents (55%) in our smaller scale on-street survey (n=114) indicated that they did not know or were unsure about the expected lifetime of VCs.

Lack of maintenance and misuse could be major factors that affect vacuum cleaner lifespans. Regular and proper maintenance is requested by manufacturers' instructions in order to keep the vacuum cleaner in good working condition and thus prolonging the mechanical lifespan.

The vacuum cleaner repair specialist recommended the following fundamental maintenance tasks, generally reported in manufacturers' instructions:

- Dust the outside of the vacuum cleaner and clean the head (i.e. brush bar) at every use
- Change the filter regularly (once a month)
- Change the belt regularly (once a month)
- Do not overfill the bag (up to 2/3 of the capacity).

However, one out of three UK users find it irritating or very irritating to even clean the brush bar (Electrolux 2013), and our survey revealed a generally negative attitude to general maintenance tasks. Half of survey respondents stated that they replace the bag or empty the container of dust when they think it is full, or when the machine does not suck properly (15%), rather than according to manufacturers' instructions (7%) or when indicated by the machine (16%). Similar responses are reported about the frequency of cleaning or changing the filters. 12% do not clean the filters or do not even know if the machine has filters. Similarly, 16% of respondents do not carry out any of the other fundamental maintenance tasks (e.g. checking that the brush bar is free from hair or dirt).

Instructions are provided by the manufacturers and widely available online. However, survey respondents admit that they do not check them or have done so only once (Figure 1). Furthermore, other sources of instructions, beyond manuals, are available on the internet and used in particular by younger population (17-35 years old). Brook Lyndhurst (2011) identified caring for products in use as an opportunity for intervention in attitudes and behaviours, especially amongst lower income consumers, with the aim of lengthening product lifetimes.

Interventions to encourage longevity might therefore aim at increasing consumers' ability to take basic care of products.

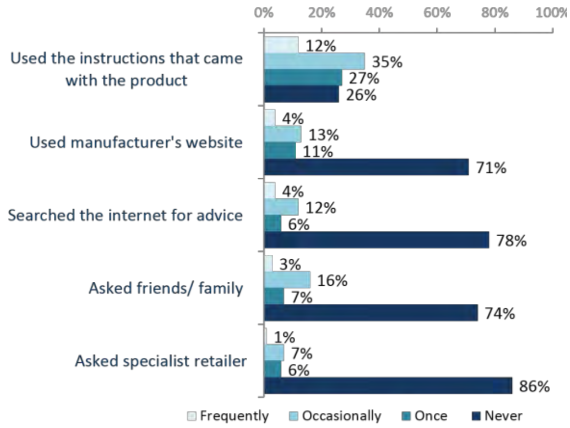

Figure 1. Sources of information and frequency of use when maintaining and repairing vacuum cleaner.

Convenience of replacement and repair

The generally negative attitudes to maintenance was also reflected when a breakdown of the vacuum cleaner is experienced. In our survey, almost 8 in 10 respondents stated that they would consider repairing their vacuum cleaner in the hypothetical case of loss of suction or if the machine did not switch on. However, only a fifth of respondents (18%) reported that their vacuum cleaner had been repaired, while 14% stated that they did not think that vacuum cleaners are worth repairing.

Rising repair costs in conjunction with falling prices of newly manufactured goods makes it increasingly difficult for consumers to justify repairs (Cooper, 1994, 2004; Downes et al. 2011; McCollough, 2007, 2010).

The first vacuum cleaners imported to Britain cost £25, roughly equivalent to a maid's annual salary (Jackson 1992). Nowadays prices are considerably lower.[3] According to the White Goods Trade Association (WGTA, 2010), over the last two decades appliance prices have dropped in real terms, with significant implications for the industry and for product lifetimes.

[3] According to Which? (2014a), the average cost of a new vacuum cleaner is £184, raising up to £279 for a Best Buy.

Although it can represent a significant service industry (Department for Professional Employees, cit. in Graham & Thrift, 2007), the repair market has significantly declined over past decades. The Professional Service Association, a New York–based trade group, reports that over the 15 years preceding 2007 the number of appliance and electronic goods service centres decreased by about 40% and 70% respectively (McCollough, 2010).[4]

The UK Government's waste prevention programme aims at promoting greater reuse and repair though the development of a tool to enable householders to find local reuse and repair services (HM Government, 2013). However, several barriers undermine the spreading of the repair market including:

- willingness to pay more than a small fraction[5] of the replacement cost to have an appliance repaired (Brook Lyndhurst 2011; Hlavacek, cit. in McCollough, 2009)
- dissatisfaction or detachment from the product (Clarke & Bridgwater, 2012; Cooper, 2004)
- consumer's confidence and trust in repairers (Darby and Karni, cit. in McCollough, 2009)
- frustration and annoyance between breakdown and completion of the repair service (Lee Woolf et al., 2012; Ziebarth 1992)
- foreclosed possibilities of maintenance and repair that might be deliberately designed in the product (Verbeek, cit. in Graham & Thrift, 2007)
- aggressive marketing strategies for buying new products that reduce demand for repair services (McCollough, 2009).

This last barrier, in combination with the previous ones, not only challenges the feasibility of the repair option (and therefore the extension of vacuum cleaners lifespans) but also contributes to shape the perception of vacuum cleaners as commodity products, as addressed in the next section.

Vacuum cleaners as commodities

16% of our survey respondents indicated that they replaced their vacuum cleaner because they wanted a new one, despite their existing one still working. Maybe surprisingly, vacuum cleaners can be subjected to a 'desire for new' (Campbell, 1992) and as for other products there could be several underpinning triggers for the acquisition of new vacuum cleaners (e.g. Shove and Warde, 2002).

The trend of replacing vacuum cleaners rather than keeping them for longer could be related to users' perceptions of their machines. The majority of our respondents (80%) keep their vacuum cleaner out of view, usually in a cupboard, perhaps due to the unpleasant appearance of vacuum cleaners. As vacuum cleaners are used and their materials deteriorate, they show scratches and grazes from use. Alongside mechanical damage, the clear shiny plastic becomes 'milky' and very fine dust collects in the complex shapes and contours of many vacuum cleaners. These qualities are liable to lead to disaffection with plastic products, even to the extent of encouraging disposal of products that still function. This is particularly the case for products associated with hygiene (Fisher 2004, Fisher and Shipton 2009), as addressed in the next section.

Attitudes toward cleanliness

Individual attitudes towards cleanliness at home have implications for the lifespan of vacuum cleaners.

Nearly three quarters of adults in the UK 'really care' about their house being clean, taking pride in maintaining a clean home (MINTEL 2013a).[6] In fact, when cleaning "we are not mainly trying to avoid disease. We are […] making visible statements about the home that we are intending to create out of the material house" (Douglas, cit. in Shove 2003, p.82).

Vacuum cleaning the floor is the third-highest priority cleaning task reported by householders (MINTEL 2013a) and a third of vacuum cleaner users in the UK feel satisfied after vacuuming (Electrolux 2013). On the other hand, our survey revealed how variable is the

[4] Contrasting findings have been gathered about trends in repair over recession periods that might increase for some studies (Adler & Hlavacek, 1976) or fall for others (McCollough, 2009).

[5] Up to a third according to the local repair specialist.

[6] In our survey, 31% of the interviewees consider the cleanliness of the house a *high* priority in their life, while the 57% consider it a *medium* one.

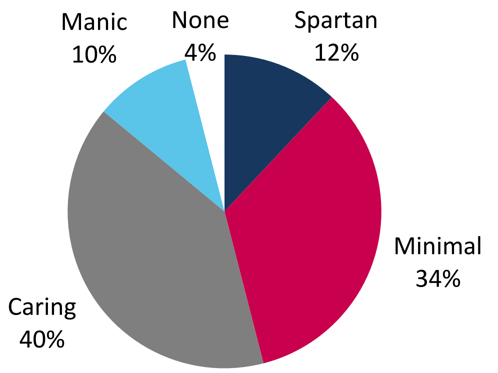

Figure 2. Clusters of attitudes towards cleanliness.

homeowner's interpretation of cleanliness and vacuum cleaning at home, as "there is no such thing as absolute dirt: it exists in the eye of the beholder" (Douglas, cit. in Shove 2003, p.82).

To this end, the results from the survey have been clustered according to attitudes towards cleanliness and vacuuming, adapting typologies from a previous study (Vaussard et al. 2014):

1. **Spartan cleaners** vacuum less than once a week and cleanliness of their house is a medium or low priority
2. **Minimalist cleaners** vacuum once a week or, if less often, cleanliness of their house is considered a high priority
3. **Caring cleaners** vacuum at least 2-5 times a week and cleanliness of the house is a high or medium priority
4. **Manic cleaners** vacuum daily.

There appears some correlation between these clusters and their attitudes towards vacuum cleaners lifespans. Manic cleaners replace the machine faster than people in the other clusters, perhaps suggesting more intensive use or their perceived need for a vacuum cleaner that always performs (Figure 3). For Manic and Caring cleaners the latter is supported by their more positive attitude towards maintenance and repair, and also by their interest in having the vacuum cleaner serviced for a convenient price (an option considered, on average, unrealistic by Spartan and Minimalist cleaners).

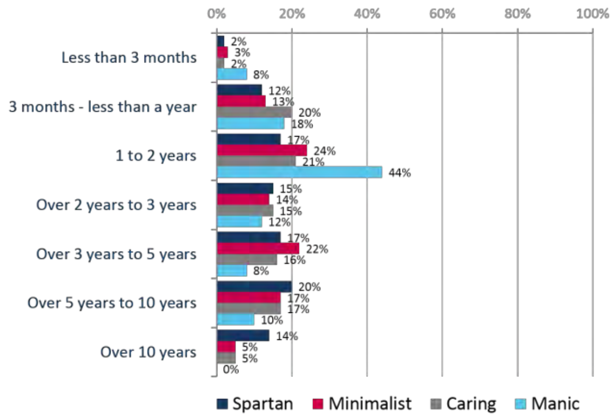

Figure 3. Lifespan of currently owned vacuum cleaners.

Meaning of vacuuming and vacuum cleaners

The investigation carried out so far reveals several factors contributing to faster replacement of vacuum cleaners, classified in this paper as unreliability, detachment, convenience, commodity and cleanliness. As mentioned above several policy interventions have attempted to address these, ranging from international regulations for component durability to manufacturing guidelines. These actions target specific issues but other possibly relevant causes of faster replacement are at risk of remaining untapped.

In fact, the EU regulation limiting the wattage of vacuum cleaners and including the minimum lifespan for certain components (European Commission, 2013) generated contrasting reactions, not only by manufacturers – who might feel undermined in the way they design and produce[7] - but also by users who bought a higher wattage vacuum cleaner before they were banned.[8]
Users may worry that such a regulation will reduce performance and therefore reduce the attainable level of hygiene or time saving that only high wattage machines are considered capable of providing. It is plausible that the introduction of higher wattage machines over time has been influencing the perception of minimum technical specification required to reach acceptable levels of hygiene. As stressed by Shove, "as cleaning technologies are enmeshed in a landscape of moral and social distinction, their development has the further

[7] http://www.telegraph.co.uk/technology/news/11075490/James-Dyson-suggests-leaving-the-EU-over-vacuum-cleaners.html

[8] http://www.dailymail.co.uk/news/article-2740197/Power-surge-Fourfold-rise-sales-super-vacuums-Some-customers-buying-two-models-beat-new-EU-regulations.html

effect of reconfiguring that terrain” (Shove 2003, p.83).

Our hypothesis is that factors leading to faster replacement reflect the type of interaction that is established between the user and the machine, or in other words with the human and non-human subjects. vacuum cleaner users appear resistant to following the instructions of optimal maintenance required for a durable and high performing machine. Regular and effective maintenance is essential to those machines. However, the human component of this ‘team’ is not aware of or engaged with it.

Vacuum cleaners could be envisaged as almost ‘magic’ machines for cleaning, as advertised on 1920s advertisements promoting the first vacuum cleaners imported to Britain: they offer “easy, effortless cleaning of every nook and corner” and provide “leisure and freedom” (Jackson 1992, p.166). Jackson (1992, p.166) concludes that “this reveals something of the mythology of the ‘mechanical servant’: it is as if the vacuum cleaner steers itself around the house unaided.”

Using Latour’s concept of delegation (1992), vacuum cleaning is the kind of practice constituted by a human-non-human hybrid involving a distribution of competences between user and machine. Although the latter is in charge of the core activity of cleaning the floors, the former is supposed to oversee the latter by ‘feeding’ it (i.e. keep un/plugging to the mains while in use), steering and maintaining it. Feeding the vacuum cleaner has been partly delegated to rechargeable batteries, and steering may be delegated to robotic vacuum cleaners.

However, the user still holds responsibility for the most fundamental task for product longevity, maintaining the vacuum cleaner. Unwilling users or those unsuccessful at carrying out maintenance effectively make this hybrid system ineffective. It may be inferred that as with the delegation of feeding and steering, humans have wished to delegate maintenance tasks to the machines themselves, expecting performance and longevity with limited effort. This expectation is not met, and when the vacuum cleaner breaks it demands attention that the human has tried to avoid by means of delegation to the machine. From this perspective, the first factor leading to the perceived brokenness, unreliability, is confirmed. vacuum cleaners are not reliable for contemporary users as they break due to their (current) inability for self-maintenance.

Conclusions

This paper addressed the factors influencing actual and perceived brokenness of vacuum cleaners. The analysis of the results of a country-wide survey revealed insights about users’ reluctance to carry out maintenance and repair that can be related to the interaction between user and product. In particular, we argue that brokenness is not necessarily an intrinsic condition of the machine but rather a perceived state in which unwanted effort is required of the user by the item.

The failure of the vacuum cleaner to reach its potential lifespan relates to users’ expectations of their performance - as if users expect the machines to maintain themselves and thereby minimise their involvement and effort. However, this is not achievable with current technologies; future interventions should perhaps target this relationship between product and user.

The design element of this project attempts to engage the user in maintenance tasks by improving the experience of use and maintenance. Enhancing the enjoyment of vacuum cleaning and the associated maintenance tasks of the vacuum cleaner is a major objective and a possible strategy to change attitudes and reactions to (perceived) brokenness. Through co-design and action-based research approaches, design-driven strategies will be investigated in future stages of the project.

Acknowledgments

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An exploratory study on the links between individual upcycling, product attachment and product longevity

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Keywords: individual upcycling; product attachment; product lifetimes; product longevity; sustainable consumption; sustainable production.

Abstract: Product attachment, the emotional bond experienced with a product, is an emerging concept for sustainable production and consumption. The logic behind it is that when people are attached to any product, they are more likely to handle the product with care and to postpone its replacement or disposal. Some types of product have been studied regarding product attachment in past research but the focus has been on the perspectives of professional designers and manufacturers rather than on consumers' 'everyday creativity' activities such as 'individual upcycling'.

Individual upcycling, creation out of used materials resulting in a higher quality or value product than the compositional elements, is particularly relevant to product attachment. This is because upcycling, as a creative, participatory user activity, may offer the experiences of self-expression, group affiliation, special memories and pleasure, all of which are possible product attachment determinants.

Recent evidence suggests that the number of upcycling practitioners have increased, possibly as a response to the contemporary 'maker movement' and aided by readily available physical and digital resources. Despite this growth and its potential as a means for sustainable production and consumption at household level, individual upcycling has not been investigated extensively, especially its relation to product attachment and product longevity.

This study used an exploratory questionnaire with 23 UK-based upcycling practitioners to investigate the links between individual upcycling, product attachment and product longevity. The results show the correlations amongst the degree, determinants and consequences of product attachment as well as aesthetic and functional satisfaction from the emotionally attached, upcycled products. The paper further explains how different demographic characteristics and product categories moderate the strength of the aforementioned variables.

Introduction

Product attachment, the emotional bond experienced with a product (Schifferstein & Pelgrim, 2003), is an emerging concept with the potential to engender sustainable consumption (Cooper, 2005; Mugge, Schifferstein, & Schoormans, 2004; Van Hinte, 1997). The logic behind it is that so long as people are attached to any product, they might be more likely to handle the product with care, to postpone its replacement or disposal, and to repair it when it breaks down (Cramer, 2011; Ramirez, Ko, & Ward, 2010; Mugge R. , Product Attachment (PhD thesis), 2007; Van Hinte, 1997), while not necessarily requiring people to commit themselves to pro-environmental behaviour (van Nes, 2010).

Some types of product have been studied regarding product attachment: for example, consumers' most favourite or most cherished possessions (e.g. family heirlooms and jewellery) (Schultz, Kleine, & Kernan, 1989; Wallendorf & Arnould, 1988) or mass-produced, ordinary consumer durables (Mugge, Schifferstein, & Schoormans, Product attachment and satisfaction: understanding consumers' post-purchase behaviour, 2010; 2006a; 2006b; 2005). Past studies have shown interests in product personalisation, mass customisation and participatory design to increase product attachment (i.e., strengthening the person-product relationship) as design strategies for sustainable consumption (Cramer, 2011; Mugge, Schoormans, & Schifferstein, Emotional bonding with personalised products, 2009a; Incorporating consumers in the design of their own products. The dimensions of product personalisation, 2009b; Fletcher, 2008; Chapman, 2005). Despite such emphasis on consumer involvement in design, past studies have not yet paid attention to 'everyday creativity' activities (Gauntlett, 2011) without involving manufacturers, such as consumers' individual making, crafting or upcycling at household level.

Individual upcycling, creation or modification of any product out of used materials in an attempt to generate a product of higher quality or value than the compositional elements (Sung, Cooper, & Kettley, 2014) at household level, is particularly relevant to product attachment since practitioners may often utilise old products with which they have already developed the emotional bond. Upcycling, as a creative, participatory user activity, may offer the experiences of self-expression, group affiliation, special memories and pleasure, all of which are possible product attachment determinants (Mugge, Schifferstein, & Schoormans, A longitudinal study of product attachment and its determinants, 2006a). In other words, individual upcycling is likely to create strong product attachment and lead to product longevity.

The evidence suggests that the overall number of upcycling practitioners have been increased or at least have become more visible, possibly as a response to contemporary Maker Movement (AndersonChris, 2012; LangDavid, 2013) and aided by readily available physical resources (e.g. Maker Faire, Hackspace/Makerspace) and digital resources (e.g. Instructables, Etsy). Despite this growth (or increased visibility) in the practice and its potential as a strategy for product longevity (and sustainable consumption), individual upcycling has not been fully investigated, especially in terms of its relation to product attachment and product longevity.

The main aims of the paper, therefore, are twofold. The first is to address the links between individual upcycling, product attachment, and its determinants and consequences including product longevity. The second is to pinpoint some possible group differences in the strength of the aforementioned variables according to demographic characteristics and product categories.

Research methodology

A questionnaire was administered to 23 UK-based upcycling practitioners. The data was collected between April and July 2014.

Procedure and measures

The upcycling practitioners were first asked to select up to three products to which they had the most emotional attachment from a list of upcycled products. They were then asked to fill in up to three identical questionnaires based on their selection.

The questions addressed (1) product attachment determinants (self-expression, group affiliation, memories and pleasure[1]) from the emotionally attached product made by upcycling; (2) aesthetic and functional satisfaction from the emotionally attached product made by upcycling; (3) product attachment; and (4) product attachment consequences (disposal tendency, product care, expected product longevity, irreplaceability, and expected product lifetime years). Measures for these variables were obtained on seven-point Likert scales (1= "strongly disagree", 7="strongly agree"), except for the expected product lifetime years (for which an absolute figure was given). See Table **1** for the descriptions of variables used in the questionnaire.

Sampling

Hackspace was considered to be an appropriate starting point for the recruitment of upcycling practitioners based on its facilities

[1] These four possible product attachment determinants were used in the study by Mugge, et al. (2006a). Their findings demonstrated that product attachment is positively affected by self-expression, memories and pleasure for ordinary consumer durables. Though group affiliation proved to be non-significant in their study, this study included it as a possible determinant because upcycling practitioners may feel affiliated to other upcyclers, makers, or material/product providers (e.g. family inheritance).

and service,[2] and growing numbers in the UK.[3] Ten workshops in ten different cities of nine different regions in England were selected.[4] A recruiting advertisement was posted on Google groups or forums of the ten workshops. Thirteen respondents directly reacted to the advertisement and another ten were identified by snowball sampling.

Self-expression	This product that I made reflects who I am.
Group affiliation	This product that I made indicates that I am a maker/ crafter/ upcycler/ hacker.
Memories	This product reminds me of people or events that are important to me.
Pleasure	I feel good when I use this product.
Aesthetic satisfaction	I am happy with the appearance of this product.
Functional satisfaction	I am happy with the functionalities of this product.
Product attachment	This product has special meaning to me and I have an emotional bond with this product.
Disposal tendency	I would like to get rid of this product.
Product care	I take good care of this product.
Expected product longevity	I hope that this product will last for a long time.
Irreplaceability	This product is irreplaceable to me.
Expected product lifetime years	For how many years would you like to use the product?

Table 1. Variable items.

Respondents

Respondents were from nine different cities and aged between 24 and 66 years old. 17 (74%) were British and 6 (26%) were non-British. 15 (65%) were male and 8 (35%) were female. 12 (52%) worked in science and engineering, 7 (30%) in art and design, and 4 (17%) in other areas (health service, business and management) or were unemployed.

Analysis

44 questionnaires from 23 respondents were analysed by employing descriptive statistics, correlational analysis (Spearman's Rank Order Correlation) and non-parametric tests (Mann-Whitney U Test and Kruskal-Wallis H Test), using SPSS (Statistical Package for the Social Sciences) version 22.0.

Results

Descriptive statistics

When respondents selected certain products as their most emotionally attached products after upcycling (M=5.41, SD=1.59), they reported high mean values of self-expression (M=5.27, SD= 1.56), group affiliation (M=5.66, SD=1.45), pleasure (M=5.59, SD=1.30), aesthetic satisfaction (M=5.75, SD=1.26), functional satisfaction (M=5.82, SD=1.45), product care (M=5.09, SD=1.36), and expected product longevity (M=5.37, SD=1.53), and a low mean value of disposal tendency (M=1.45, SD=.92). Memories and irreplaceability data showed slightly lower mean values with a larger standard deviation (memories: M=4.41, SD=2.37; irreplaceability: M=3.61, SD=2.34). The expected product lifetime years ranged between 1 year and over 50 years, resulting in the mean value of 11.67 (SD=13.23).

Correlations between product attachment (PA) determinants, aesthetic and functional satisfaction, and PA based on the most emotionally attached, upcycled products Spearman's Rank Order Correlation revealed that PA is positively correlated with all four PA determinants (self-expression, group affiliation, memories and pleasure) (r=.45 to .66, p<.001), but not with satisfaction from aesthetic or functional qualities. PA determinants are mostly positively correlated with each other: only group affiliation and pleasure are not significantly correlated. Pleasure is positively correlated with functional satisfaction but not with aesthetic satisfaction, although there is significant

[2] Hackspaces provide any local residents (e.g. craft hobbyist, hackers, makers, tinkerers, artists, entrepreneurs, etc.) with a membership including the access to tools, materials and expertise.
[3] Hackspaces have increased in numbers since 2009 and are now available in 53 different locations (UK Hackspace Foundation, 2015).
[4] The selected workshops included (1) Nottingham Hackspace (Nottingham, East Midlands); (2) Makespace (Cambridge, East of England); (3) London Hackspace (Greater London); (4) MakerSpace (Newcastle upon Tyne, North East England); (5) HACMan (Manchester, North West England); (6) Build Brighton Hackspace (Brighton, South East England); (7) Reading Hackspace (Reading, South East England); (8) OxHack (Oxford, South West England); (9) Potteries Hackspace (Newcastle-under-Lyme, West Midlands); and (10) Leeds Hackspace (Leeds, Yorkshire and the Humber). The selecting criteria were accessibility to and activeness of the Hackspace members.

correlation between functional and aesthetic satisfaction (see Table 2).

	SE	GA	M	P	AS	FS	PA
Self-expression	-						
Group affiliation	.515**	-					
Memories	.631**	.461**	-				
Pleasure	.692**	.351	.519**	-			
Aesthetic satisfaction	.288	.337	.059	.361	-		
Functional satisfaction	.236	.224	.105	.490**	.558**	-	
Product attachment	.664**	.451**	.627**	.644**	.309	.213	-

Table 2. Spearman's rho between PA determinants, satisfaction, and PA based on the most emotionally attached, upcycled products ** p<.001 (2-tailed).

	DT	PC	EL	I	EY	PA
Disposal tendency	-					
Product care	-.343	-				
Expected product longevity	-.365	.679**	-			
Irreplaceability	-.122	.442**	.479**	-		
Expected product lifetime years	-.363	.252	.445**	.237	-	
Product attachment	-.274	.371	.364	.516**	.363	-

Table 3. Spearman's rho between PA and PA consequences based on the most emotionally attached, upcycled products. **p<.001 (2-tailed).

Correlation between product attachment (PA) and PA consequences based on the most emotionally attached, upcycled products

Spearman's Rank Order Correlation showed that PA is positively correlated with irreplaceability (*r*=.516, *p*<.001) but there is no statistically significant correlation of PA with disposal tendency, product care, expected product longevity, or expected product lifetime years. Irreplaceability, however, is positively correlated with product care (*r*=.44, *p*<.001) and expected product longevity (*r*=.48, *p*<.001) as well as PA. Expected product longevity is also positively correlated with expected product lifetime years (*r*=.45, *p*<.001) (see Table 3).

Group difference based on demographic characteristics

Gender difference

A Mann-Whitney U Test revealed a statistically significant differences between male and female answers in PA, self-expression, group affiliation, memories, pleasure, product care, expected product longevity, irreplaceability, and expected product lifetime years.

	U	Z	Sig.	r	Md	n
Self-expression	76	-2.89	.000**	.57	M: 4 F: 7	27 17
Group affiliation	121	-2.72	.007**	.41	M: 6 F: 7	27 17
Memories	111	-2.92	.003**	.44	M: 4 F: 7	27 17
Pleasure	146	-2.08	.038**	.31	M: 5 F: 7	27 17
Product attachment	113	-2.89	.004**	.44	M: 5 F: 7	27 17
Product care	92	-3.21	.001**	.49	M: 4 F: 6	27 16
Expected product longevity	87	-3.34	.001**	.51	M: 5 F: 7	27 16
Irreplaceability	108	-2.97	.003**	.45	M: 2 F: 6	27 17
Expected product lifetime years	138	-1.96	.050**	.30	M: 4 F: 15	27 16

Table 4. Mann-Whitney U Test, effect size, and median scores with significant difference across gender groups. **p<.05.

In all cases, the median scores from female respondents are higher than males. A large effect was shown in self-expression (*r*=.57) and expected product longevity (*r*=.51). Aesthetic and functional satisfaction, and disposal tendency did not show gender difference (see Table 4).

Age difference

A Kruskal-Wallis Test revealed a statistically significant difference across three different age groups (Gp1, *n*=23: 20-29yrs, Gp2, *n*=13: 30-49yrs, Gp3, *n*=8: 50+yrs) in group affiliation: X^2 (2, *n*=44)=7.12, *p*=.028; pleasure: X^2=6.75, *p*=.034; and functional satisfaction: X^2=7.37, *p*=.025. The older the age group, the higher was the median score. Self-expression, memories, aesthetic satisfaction, PA and all PA consequences did not show age difference (see Table 5).

	X^2	Sig.	Md	n
Group affiliation	7.12	.028**	Gp1: 5 Gp2: 6 Gp3: 7	23 13 8
Pleasure	6.75	.034**	Gp1: 5 Gp2: 6 Gp3: 7	23 23 8
Functional satisfaction	7.37	.025**	Gp1: 6 Gp2: 7 Gp3: 7	23 13 8

Table 5. Kruskal-Wallis Test and median scores with significant difference across three age groupsp<.05**

Occupational difference

A Kruskal-Wallis Test revealed a statistically significant difference across three different occupational groups (Gp1: art and design, Gp2: science and engineering, Gp3: other – see above in Respondents) in self-expression, memories, product care, expected product longevity and irreplaceability.

	X^2	Sig.	Md	n
Self-expression	7.72	.021**	Gp1: 7 Gp2: 5 Gp3: 6.5	13 23 8
Memories	8.36	.015**	Gp1: 7 Gp2: 3 Gp3: 6.5	13 23 8
Product care	10.17	.006**	Gp1: 5.5 Gp2: 4 Gp3: 6.5	12 23 8
Expected product longevity	12.74	.002**	Gp1: 7 Gp2: 4.5 Gp3: 7	13 22 8
Irreplaceability	18.56	.000**	Gp1: 5 Gp2: 2 Gp3: 7	13 23 8

Table 6. Kruskal-Wallis Test and median scores with significant difference across three occupational groups. **p<.05.

For self-expression and memories, 'art and design' reported the highest median scores (both *Md*=7). For product care and irreplaceability, 'other' reported the highest median scores (Md_{CARE}=6.5, Md_{IRRE}=7). For expected product longevity, 'art and design' and 'other' reported the same higher median score (both *Md*=7) than 'science and engineering'. 'Science and engineering' reported the lowest median scores in all five variables (see Table 6).

Group difference based on product categories

A Kruskal-Wallis Test revealed a statistically significant difference in irreplaceability levels across five different product category groups (Gp1, *n*=14: experimental and/or artistic projects, Gp2, *n*=10: inside-the-home furniture, Gp3, *n*=8: garden, shed, workshop and/or outdoor products, Gp4, *n*=6: small home products and/or decorations, Gp5, *n*=6: other personal belongings), X^2(4, *n*=44)=11.02, *p*=.026 (See Appendix for item examples of each product category group). Small home products and/or decorations recorded the highest median score (*Md*=6.5), followed by other personal belongings (*Md*=5.5) and inside-the-home furniture (*Md*=3.5). Experimental and/or artistic projects (*Md*=2) and garden, shed, workshop and/or outdoor products (*Md*=1.5) showed lower median scores than other product categories.

Discussion

The statistically significant correlation between PA and PA determinants confirms findings from past studies on ordinary consumer durables (e.g., (Mugge R. , Product attachment, 2007; Schifferstein, Mugge, & Hekkert, 2004). This might suggest that the causal relationship between PA determinants and PA in consumer durables can also be applied to upcycled products.

The positive correlation between pleasure and functional satisfaction but lack of statistically significant correlation between PA and satisfaction from appearance or functionalities also partially corroborate the results from Mugge, et al. (Product attachment and satisfaction: understanding consumers' post-purchase behaviour, 2010). One difference is that pleasure in this study is not significantly correlated with aesthetic satisfaction, which implies that the sampled makers' (or upcyclers') pleasure from their upcycling outcomes may be a result of satisfactory functions but not necessarily a result of superior appearance.

The correlation between PA and PA consequences in this study is limited, unlike findings from other existing studies (i.e.

irreplaceability, product care, expected product longevity, etc.) (Ramirez, Ko, & Ward, 2010; Mugge R. , Product attachment, 2007; Govers & Mugge, 2004). Only one significant correlation was found between PA and irreplaceability. Considering the positive correlation between irreplaceability and product care, and between irreplaceability and expected product longevity, however, it might be the case that irreplaceability for makers/upcyclers mediates the effect of PA on product care and expected product longevity. Irreplaceability as a crucial condition for a long-lasting relationship was also pointed out by Mugge and her colleagues (Design strategies to postpone consumers' product replacement: The value of a strong person-product relationship, 2005).

Older age groups' higher scores in group affiliation, pleasure and functional satisfaction as well as women's higher scores in PA, all four PA determinants, and part of PA consequences partially correspond with past research that group affiliation and memories are more relevant for women and older consumers, whereas pleasure from functionality is more relevant for men and younger consumers (Dyl & Wapner, 1996; Kamptner, 1991; Chikszentmihalyi & Rochberg-Halton, 1981; Furby, 1978 cited in Mugge, 2007). One original finding on demographic difference might concern occupational difference: the science and engineering group showed lower median scores in self-expression, memories, product care, expected product longevity and irreplaceability. This, however, could be explained by the fact that almost 90% of science and engineering group respondents were male. These group differences based on demographic characteristics may suggest which group of people has to be targeted (or not targeted) in the case that individual upcycling is considered for scaling up to make a bigger impact on environment and society.

The higher median scores in irreplaceability from small home products and decorations, and other personal belongings than from inside-the-home furniture, experimental and artistic projects, or garden, shed, workshop and outdoor products conform with the study by Schifferstein, et al. (Designing consumer-product attachment, 2004), which found that PA is higher for ornaments than functional products (e.g. lamp, clock and car). Such product category difference should also be taken into account when scaling up is considered.

Conclusion

This exploratory study has described how product attachment determinants and level of satisfaction from the aesthetic and functional qualities of the emotionally attached, upcycled products are correlated with the extent of product attachment; and how the extent of product attachment is correlated with the consequences of product attachment. The paper further explained how different demographic characteristics and product categories moderate the strength of product attachment and, its determinants and consequences as well as aesthetic and functional satisfaction.

The results are, however, based on a limited sample. Moreover, as respondents were not asked questions about every upcycled product, potentially interesting areas have not been addressed, such as identifying the proportion of all upcycled products that exhibit meaningful levels of product attachment. Future research can also take into account the possible rebound effect (e.g. using more materials and energy for the purpose of upcycling) and the actual environmental impact accordingly (i.e. in terms of total materials and energy involved, and waste and emissions produced during upcycling).

Notwithstanding these limitations, this study has demonstrated that individual upcycling has the potential as a means towards sustainable production and consumption at household level by strengthening product attachment, and explained demographic characteristics and product categories to consider for possible scaling up.

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Appendix: Item examples of each product category group.

Gp	Group name	Item examples
Gp1	Experimental and/or artistic projects	Raspberry pi project Tour robot Sculpture
Gp2	Inside-the-home furniture	Nest of tables Side board TV stand
Gp3	Garden, shed, workshop and/or outdoor products	Bug boxes Patio and path Bird box Compost bin
Gp4	Small home products and/or decorations	Lamp Kettle Cushion
Gp5	Other personal belongings	Jumper Prom dress Jewellery

Service lifetime and storage time of devices with liquid crystal displays

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Keywords: service lifetime; storage time; dynamic material flow analysis; indium.

Abstract: Electronic devices contain many important resources, including critical chemical elements such as indium or neodymium. For an efficient management of these resources, it is important to know where the devices are located, how long they are used for and when and how they are disposed of. This article presents a dynamic material flow analysis of devices with liquid crystal displays; i.e. flat screen televisions and monitors, laptops and mobile phones, and the subsequent indium flows in Switzerland. The stock of the use phase within the material flow system has been split into an in-use stock and a storage stock. The outflows have been modelled by applying two lifetime distribution functions, one for the service lifetime and one for the storage time. Results highlight the importance of the storage time, being for flat screen TVs of 2.6 years, and for monitors, laptops and mobile phones of over 4 years. For monitors and laptops, the storage stock accounts for around 20%, and for mobile phones 35% of their total stock. These devices in Switzerland represent an indium stock of over 1'800 kg, an indium inflow with new products of 200 kg/year and an outflow with discarded devices of only 90 kg/year. Outflows of the model that includes storage time are significantly lower and show better congruence with actually measured flows. This shows that the storage time slows down the reintegration of secondary resources into the material cycles and therefore increases the stock of resources.

Introduction

Stocks and flows of electronic devices and the critical materials they contain have been subject to various recent investigations (Böni & Wäger, 2015; Buchert et al., 2012; Buchert et al., 2009; Sander et al., 2012; Yoshimura, et al., 2013). Devices with liquid crystal displays (LCDs) are an important field of application of indium tin oxide (ITO) (Erdmann & Behrendt, 2011). Efforts to specifically recover indium from LCDs are only just beginning and are hampered by small concentrations of indium per display, low indium prices that make recycling unattractive and limited knowledge on stocks and flows of LCDs.

Dynamic material flow analysis (MFA) is often used to analyse the development of material cycles over time. The product lifetime, which is essential for computing past and future stocks and outflows from inflow data, has been modelled in dynamic MFAs mostly by assuming average lifetimes or lifetime distribution functions for devices in the in-use stock (Müller et al., 2014). It has been discussed in many MFA studies that the modelled stocks and flows are highly sensitive to the chosen lifetime distribution functions and their parameters (Chen & Graedel, 2012; Liu et al., 2011; Müller et al., 2006). This poses various challenges: There are many different definitions of what is covered by the product lifetime (Murakami et al., 2010). Field data regarding how long the various electronic devices are used and stored is scarce and often based on rough estimations or expert opinions. Comparisons of modelled and actual flows of devices have shown that products are often much older than what models predict (Stocker et al., 2013). This highlights that models often neglect or underestimate storage time, which is considered as the time between the active use of a device and its final disposal or its passing to a different user. In this article, we present a dynamic MFA of devices with LCDs, i.e. flat screen televisions (TVs) and monitors, laptops and mobile phones, and the subsequent indium flows in Switzerland. In order to meet the challenges of finding the lifetime distribution functions and their parameters, we conducted an online survey on the service lifetime (which corresponds to the time of active use) and storage time of electronic devices in Switzerland.

Method

Model development

The MFA system includes the process 'use phase'. Based on the results of the survey, the use phase was split into the two sub processes: 'active use' and 'storage', which both store material and build the in-use stock and the storage stock. The system has one inflow which corresponds to sales of new devices and one outflow as the final disposal of obsolete items. Internal flows include the flow from 'active use' to 'storage' and vice versa as well as the direct reintegration into the in-use stock (
Figure).

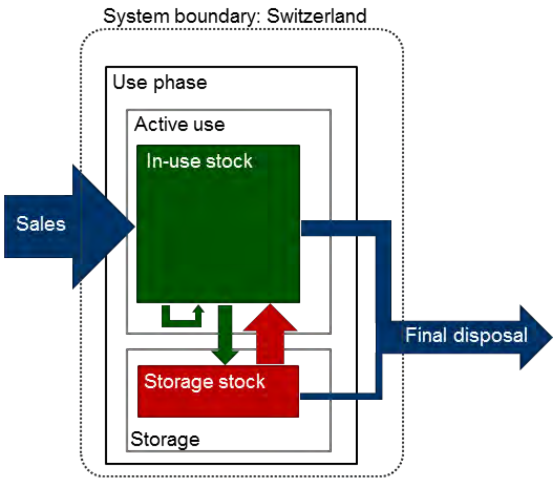

Figure 1. MFA system.

The model employs a retrospective top-down approach, deriving the stock S[n] at a time n from the net flow by using the balance of masses (equation 1), with the constant sampling rate T = 1 year (Müller et al., 2014).

$$S[n] = (inflow[n] - outflow[n]) \cdot T + S[n-1] \quad (1)$$

The outflows of the in-use stock and the storage stock were calculated according to equation 2 (Müller et al., 2014). The model applies two different lifetime distribution functions f[m], one for the service lifetime and one for the storage time.

$$Outflow[n] = \sum_{m=-\infty}^{\infty} Inflow[n-m] \cdot f[m] \quad (2)$$

The pathways of the outflows to final disposal, storage or back to the in-use stock for a second use were determined by transfer coefficients. In order to calculate the indium flows, the stocks and flows of the dynamic MFA were multiplied with the respective indium content per device.

Data collection

Sales data for laptops and flat screen monitors from 1998 to 2013 were taken from an annual ICT market report for Switzerland (Weiss, 2013). For flat screen TVs and mobile phones, sales data from 1998 and 2003, respectively, up to the year 2005 were available from the Swiss Consumer Electronics Association (SCEA, 2005), and subsequently up to 2013 were obtained from the market research institution GfK. (GfK, 2013; GfK Retail and Technology, 2007, 2008).
The lifetime distribution functions and transfer coefficients were derived from the results of an online survey that was conducted between January and May 2014 in Switzerland. It included questions on devices that were still in use, devices that were stored and already disposed of devices. For each item, information was collected on:

- the year the device was put on the market
- the condition of the device when it was purchased by the current user (new/second hand)
- the total service lifetime (for devices still in use including the years the user intends to continue to use it)
- for second hand devices the division of the service lifetime into first and second use
- the storage time (for devices still stored including the years the user intends to continue to store it)
- for second hand devices the storage time after the second use
- the disposal pathway (final disposal, storage or reintegration into the in-use stock).

With a Swiss population of 8,000,000 a confidence level of 95% and a margin of error of 5%, we needed a sample size of at least 385 people. In total, we had 439 valid responses to our survey, resulting in 981 data sets for laptops, 349 for monitors, 351 for TVs and 1,690 for mobile phones. In order to derive the lifetime distribution functions, we fitted a two-parameter Weibull distribution function to the relative frequency histograms of the total service lifetime as well as the storage time using the Origin Software (OriginLab, 2014). From our survey, we had no service lifetime and storage time data for devices that are reintroduced into the in-use stock directly after use or after storage. We assumed that they had a similar service lifetime as the second use of the second hand devices covered by our survey. Therefore we fitted a Weibull distribution function to the normalized histograms of the service lifetime of the second use. Likewise, for devices that are stored after the reintroduction into the in-use stock, we considered the storage time after the second use from the survey data.

Figure shows an example of the resulting Weibull distribution functions for mobile phones.

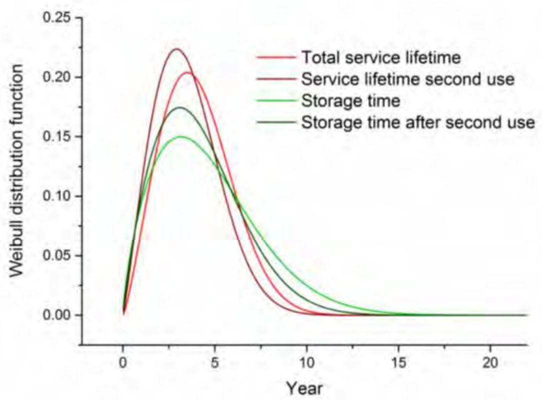

Figure 2. Different Weibull distribution functions used for modelling stocks and flows of mobile phones.

Indium is not only contained in LCDs but also found in printed circuit boards. The indium content was taken from literature (MoE and METI, 2010; Sander et. al, 2012) and own measurements (Böni & Wäger, 2015; Wäger et al., 2014). For devices with various data available, the average indium content was taken.

Results

Service lifetime and storage time

The mean total service lifetime of the resulting Weibull distribution functions ranges from 4 years for mobile phones to 8.7 years for TVs. The mean storage time is shortest for TVs with 2.6 years and longest for mobile phones with 4.7 years (
Table). The longest storage time amounts to 7 years for TVs, 9 years for monitors and 16 years for laptops and mobile phones.

Device	Mean total service lifetime [years]	Mean storage time [years]
Monitor	7.2	4.1
TV	8.7	2.6
Laptop	6.3	4.3
Mobile phone	4.0	4.7

Table 1. Total service lifetime and storage time.

Inflow

The sales of the considered devices with LCDs have all been declining in the past years, partly due to market saturation, but partly also due to a change in the electronics market to smaller, more flexible systems such as tablet computers. These new devices, though not included in our study, show a large increase in the past 4 years (
Figure).

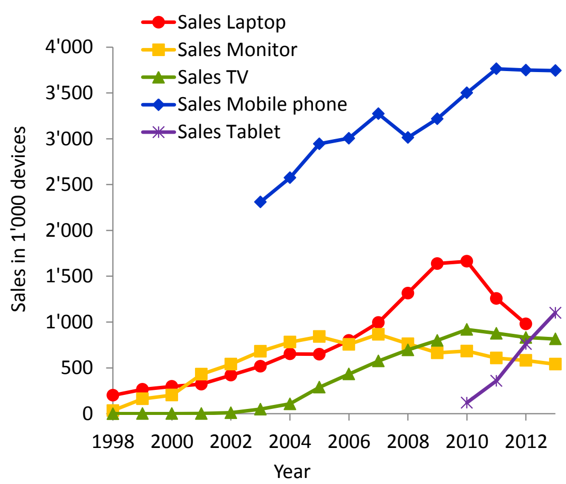

Figure 3. Sales from 1998 to 2013 in 1'000 devices. Source: GfK, SCEA, Weissbuch.

Stock

The in-use stock and storage stock calculated by the dynamic MFA are illustrated in Figure and
Figure . Mobile phones represent with 46% in 2013 the largest share of the in-use stock in terms of number of devices, followed by laptops with 23%. Measured in tonnes, it is obviously the opposite and TVs form the largest stock, followed by monitors (63% and 20%, respectively, of the total in-use stock in 2013). The in-use stock growth has declined for all devices in the last 3 years, mostly due to the decrease in sales.

The stored mobile phones represent 35% of all mobile phones in the use phase, for laptops and monitors the share of stored devices is around 20% and stored TVs account for 3% of all TVs. The storage stock is still growing linearly with the highest growth rate for mobile phones. Regarding the number of devices, the total storage stock accounts for 26% of the total stock of the use phase, regarding the mass, the total storage stock only represents 10%.

Outflow

The share of outflowing devices that are stored after their active use ranges from 31% for TVs up to 66% for mobile phones. The share of reuse and disposal is highest for TVs with 27% and 42%, respectively.

Table lists all transfer coefficients of the outflow of the in-use stock. The outflows from the in-use and the storage stock to final disposal calculated by the dynamic MFA are illustrated in
Figure . For mobile phones, the flow to disposal has recently been dominated by outflows of the storage stock. For TVs it is the opposite as outflows are mainly coming directly from the in-use stock. For laptops and monitors, outflows of the in-use stock and the storage stock are of similar size. The outflows are still growing for all devices.

Indium

The considered devices in Switzerland represent an indium stock of 1800 kg, an indium inflow with new products of 200 kg/year and an outflow with discarded devices of only 90 kg/year in 2013. The stock is dominated by TVs, monitors and laptops. Mobile phones with their smaller displays only account for 6% of the total indium stock. The total storage stock adds up to 290 kg or 15% of the total indium stock (
Figure).

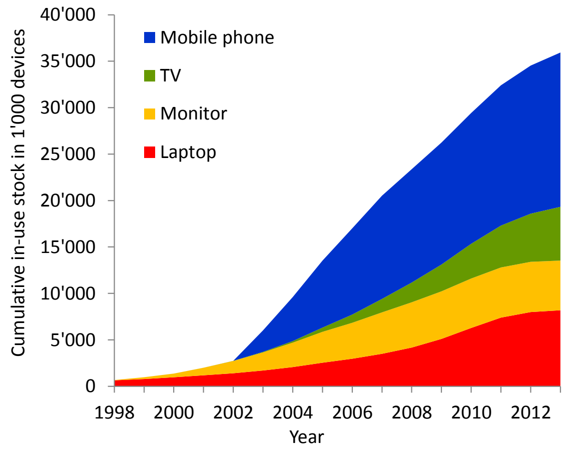

Figure 4. Cumulative in-use stock between 1998 and 2003 in 1,000 devices.

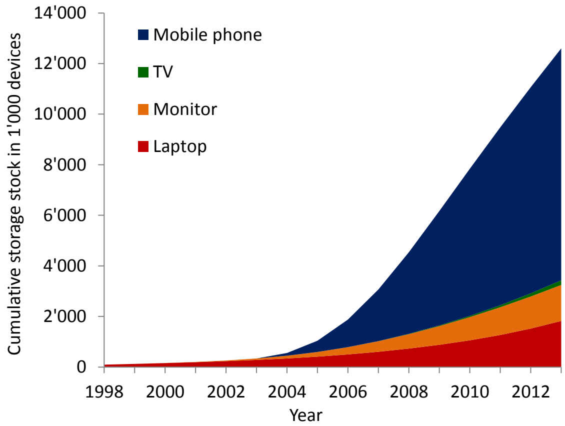

Figure 5. Cumulative storage stock between 1998 and 2003 in 1,000 devices.

Device	Storage	Reuse	Disposal
Laptop	0.60	0.16	0.24
Monitor	0.53	0.18	0.29
TV	0.31	0.27	0.42
Mobile phone	0.66	0.11	0.23

Table 2. Transfer coefficients of the outflows of the in-use stock.

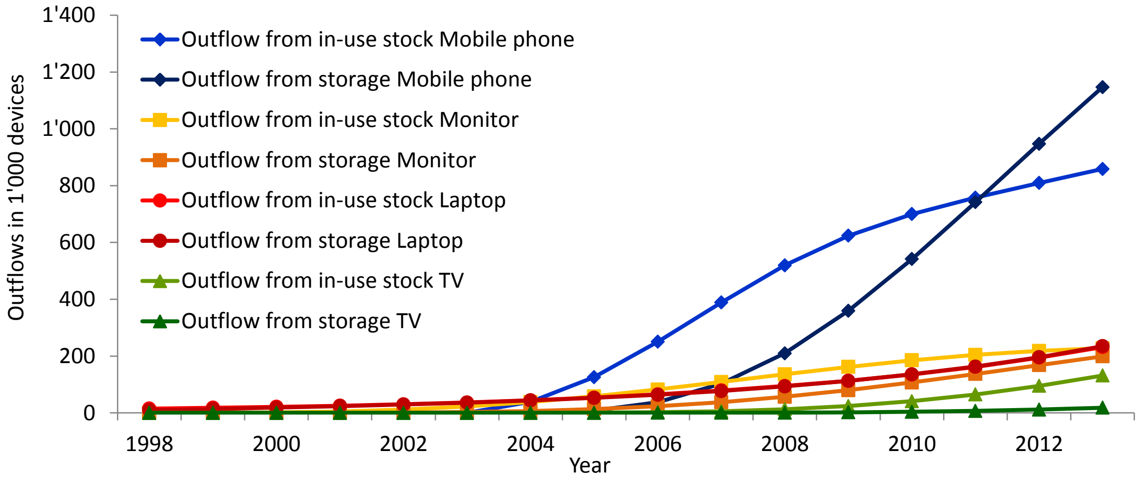

Figure 6. Outflows from storage and in-use stock to final disposal from 1998 to 2013 in 1,000 devices.

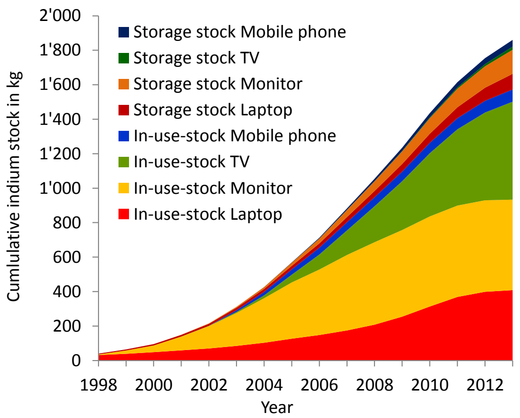

Figure 7. Cumulative indium in-use and storage stock in kg.

Discussion

The total service lifetime is highly influenced by the service a device provides. For TVs and monitors, producers and content provider ensure through backward compatibilities that older devices are still able to display current media streams. New devices basically provide the same service (among others), with higher resolution and probably on larger screens. Therefore, TVs and monitors have the longest mean total service lifetime. In contrast, laptops and mobile phones and their software are subject to fast innovation cycles, so that new devices are bought due to their additional functionality. In addition, these mobile devices become obsolete more frequently due to hardware failure such as insufficient battery life or broken displays.

The transfer coefficients after the active use to storage, reuse and disposal demonstrate that the smaller a device, the more often it is stored after its use. However, besides the size, an important reason that mobile phones and laptops are rather stored than disposed of immediately after use might be their ability to store personal data such as photos, files or messages. Instead of transferring these data to a new device or a cloud service, the device itself is often stored. Mobile phones are also stored as a backup for the actively used phone that could get broken or lost. The reintegration into the in-use stock is highest for TVs, probably due to the above mentioned fact that older devices are still able to provide the required service. Monitors, where the same reasoning would apply, have become so cheap that most likely rather new devices are purchased than old ones reused.

The storage time is again mostly influenced by the size but probably also by the personal attachment to a device (Remy & Huang, 2015). Therefore, mobile phones and laptops are kept for the longest time.

If we compare the number of devices in the in-use stock with stock data of Swiss Statistics (BFS, 2012a, 2012b), the model seems to overestimate the in-use stock for all devices.

This could be due to the fact that our survey only covers the private use of devices. Lifetime and disposal pathways of electronic devices in business use differ greatly from private use as devices are often replaced faster. The transfer coefficients to storage, the storage time and the resulting size of the storage stock, even if it might also be overestimated, highlights the importance of taking into account storage in MFA. If storage was neglected, the calculated outflows would for example be 46% higher for mobile phones and 42% higher for TVs. Compared with actual flows in the Swiss e-waste system (Swico, SENS, SLRS, 2013), one sees that, e.g., for mobile phones, the computed flows are still too high but for TVs the flows correspond quite well (Figure 8).

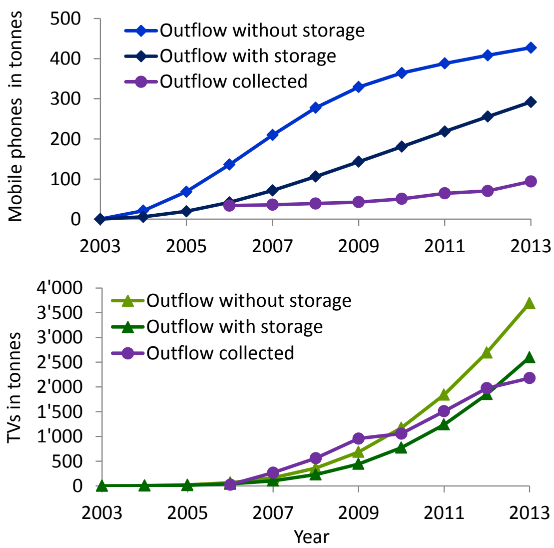

Figure 8. Comparison of outflows with and without storage taken into account. Source: Swico.

The reason might be that disposed of mobile phones reach other disposal pathways such as municipal waste, donations for exports etc. whereas TVs are rather disposed of in the official channel. Devices that reach the official Swiss e-waste system are manually and mechanically dismantled and sorted into different material fractions such as metals, plastics, printed circuit boards etc. When recycling LCDs, great importance is attached to the environmentally sound removal and disposal of the mercury containing backlights. Critical metals such as indium are not recovered. The LCD panels containing indium are either stored or incinerated with indium lost to the slag. Current projects aim at finding technologies and financing mechanisms for recycling indium in LCDs (Böni & Wäger, 2015).

This would enable the reintegration of the current indium stock of about 1,800 kg into the material cycle.

Conclusions and outlook

The modelling of product lifetimes is an essential part of dynamic MFA. Product lifetimes are mostly defined as the service lifetimes of products. However, many products are stored after their active use and before they are finally disposed of. In this article, we proposed a model that takes into account consecutively both the service lifetime and the storage time. We investigated the effect of such an extended model on stocks and flows of devices with LCDs. Our results show that especially for small devices, such as mobile phones, which contain valuable resources, storage time should always be considered when product lifetime is explored. Outflows of the model that includes storage time are significantly lower and show better congruence with actually measured flows. However, the presented model tends to overestimate stocks, partly because it does not distinguish between private and business use. Future research should therefore explore and include the service lifetime and storage time of business use. It should also investigate different disposal pathways, since for some devices, outflows still seem too high compared to actually collected flows. Parameters such as Weibull parameters or transfer coefficients could also be further optimized for better correspondence of the model results with actually measured stocks and flows. And finally, as online surveys often have a selection bias, the representativeness of the empiric data should be further verified.

The storage time slows down the waste generation as well as the reintegration of secondary resources into the material cycles and therefore increases the stock of resources. It does not contribute to product longevity and the resource efficiency of electronic devices, since products are replaced once they become obsolete, regardless of whether they are stored or disposed of. However, for an efficient resource management, it is primarily important that devices are brought to collection after use or storage, in order to ensure adequate recycling. Our modelling approach contributes to the understanding of current stocks and flows of devices with LCDs, which is an important basis for further measures towards resource efficiency and waste reduction.

Acknowledgments

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A product design framework for a circular economy

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Keywords: circular economy; circular product design; design guidelines; product life extension.

Abstract: The paper provides a circular economy framework from a product design perspective with tools to aid product designers in applying circular product design in practice. Design research for circular economy has so far mainly been limited to referring to existing fields of research such as design for disassembly, remanufacturing and recycling. The implications of combining these fields in the context of circular economy from a product design perspective however have remained largely unexplored. Furthermore, available aids for product designers are limited. A critical review of current 'circular economy' terminology led to the (re)definition the five most design-relevant topics: future proof design, and design for disassembly, maintenance, remake and recycling. With this an adapted circular economy model was proposed. Next, several tools were developed to aid a designer with the application of circular product design. The tools were tested and validated with Philips designers and engineers. A Philips case study was used in the development and application of the tools.

Introduction

Circular Economy (CE) describes a model of closing material loops in an economically attractive way to decouple wealth from resource usage. The model addresses the challenges of today where the consumption of a growing population is leading to unsustainable usage of finite resources with increased price volatility and higher prices (Ellen MacArthur Foundation, 2012). CE is based on five principles, inspired by natural systems: design out waste, build resilience through diversity, shift to renewable energy sources, think in systems and think in cascades (Ellen MacArthur Foundation, 2013). In the case of products changes can be made by business strategies (e.g. leasing products) and product design (e.g. longer lasting products).

The concept of CE is certainly not new as it is derived from several schools of thought such as biomimicry, cradle-to-cradle, the blue economy, industrial ecology and the performance economy. So what exactly is circular product design? There are only a few definitions presented in literature:

> *"Circular design, i.e. the improvements in material selection and product design (standardisation and modularisation of components, purer material flows, and design for easier disassembly)"* (Ellen MacArthur Foundation, 2012).

> *"Circular product design: Elevates design to a systems level (1), Strives to maintain product integrity (2), is about cycling at a different pace (3), explores new relationships and experiences with products (4) and is driven by different business models (5)"* (Bakker, Hollander, van Hinte, & Zijlstra, 2014)

These descriptions provide a general overview of what circular product design is but are not clearly related to the CE model and are not part of a framework with more detailed information to aid product designers. Design research for circular economy has so far mainly been limited to referring to existing fields of research such as design for disassembly, remanufacturing and recycling. However, guidelines from different areas of expertise sometimes overlap. Modularity as a design principle is part of the disassembly and remanufacturing literature (Mital, Desai, Subramanian, & Mital, 2008) (Ijomah, McMahon, Hammond, & Newman, 2010) while disassembly as a design principle can be found in the modularity and remanufacturing literature. Of the several Design for Excellence (DfX) methods remanufacturing is the most encompassing, including disassembly, cleaning, reassembly and testing guidelines. Remanufacturing however is approached from a single product view lacking the system approach thinking of CE. The implications of combining these fields in the context of circular economy from a product design perspective however have remained largely unexplored. Some examples exist where guidelines from different DfX disciplines have been combined in a CE context (Poppelaars, 2013) (University of Cambridge, Institute for Manufacturing , 2013), but give mainly a summary of guidelines and lack new insight. Furthermore, available aids for product designers are limited.

Therefore this paper will aim to bring a clear understanding of circular product design and present a framework and aids for product design in a circular economy.

The central research question is: "What is circular product design and how can it be applied in the design process?"

Methodology

The results are based on insights gained during a TU Delft, Faculty of Industrial Design Engineering Master graduation project at Philips in Eindhoven, The Netherlands, in 2014. A literature review led to the development of the guideline overview. Interviews and workshops with experts at Philips and the design of a concept luminaire were used to develop and verify the results. B2B indoor LED lighting was used as a case study for the development and application of the framework. The research approach was taken from product design perspective, leaving out business related aspects and primarily focused on the technological lifecycle to ensure manageability.

Results

Adapted circular economy model

In order to describe a circular product design framework a set of definitions needed to be developed that are all inclusive, fully applicable to product design and with a single interpretation of the terminology used. The currently best known CE model (Ellen MacArthur Foundation, 2013) is not all inclusive (lack of time aspect), not fully applicable to product design (reuse/redistribute circle) and there are multiple interpretations of the terminology used (reuse, refurbish, remanufacture) resulting in misunderstanding and discussion. Therefore, an adapted model is proposed (Figure 1) from a product design perspective, the circular product design model. The five main characteristics will now be explained, from the inner loop to the outer loop.

Future proof

CE addresses the unsustainable resource usage by closing the loop via several circles. This only works if all resources can be fully recycled without loss of quality and the whole system runs on renewable energy sources. Without those conditions a time aspect needs to be included to focus on slowing down the process. This could be done by reducing the need for new products, for instance by making longer lasting (functional) products that will be used longer (desirability), i.e. future proof.

Disassembly

Disassembly is the first step in most actions performed to the product in order to either extend its lifetime or to give a new life to the materials. Optimizing product disassembly can best be done at the design stage where 80-90% of disassembly gains are determined (Desai & Mital, 2003) in contrast to optimization of the disassembly processes. For maintenance and remake non-destructive disassembly should be prioritized, destructive disassembly is more appropriate for recycling (Peeters, Vanegas, Dewulf, & Duflou, 2012). To avoid overlap between the circles and its importance to the design process disassembly is mentioned as a separate topic. Disassembly can be subdivided into connections and product architecture. While the literature mostly discusses fasteners (Peeters, Vanegas, Dewulf, & Duflou, 2012) (Mital, Desai, Subramanian, & Mital, 2008) the word connections removes the restriction in limiting thinking to fasteners. Connections can also be made without fasteners, e.g. by a form fit or welding. The product architecture facilitates the ease and speed of disconnecting those connections.

Maintenance

Maintenance is the prolonged use of products and consists of all aspects related to delivering performance for as long as possible in the use phase. This includes cleaning, repair, upgrade and lifetime prognostics. From a design perspective, optimal maintenance also includes designing a product with lifetime prognostics, which allows predicting the future performance of a product. Such predictive tools can include tracking of use conditions and can be a strong enabler for service-based business.

Remake
Remake is the prolonged use of components and consists of all actions performed when a product returns back from the customer.
Remake is used as an umbrella term for refurbishment, remanufacturing and reconditioning since they are interpreted different per industrial sector (Parker, 2007). Modularity is of key importance: modules should be defined to allow effective repair and upgrading, which also implies that common interfaces between modules are desired. Also in this stage lifetime prognostics, i.e. assessment of the remaining reliability is of importance. Reverse logistics whereby additional transportation changes the economics can influence design decisions on the product (e.g. improved stackability) and location (e.g. local production).

Recycling
Recycling consists of material recovery at end-of-life and is the last option to recover any remaining value that a product or component has. This means that, in contrast to all previous aspects, recycling in CE is a mandatory requirement for every product. In recycling disassembly for low-value products is often destructive. Partial non-destructive manual disassembly can be used to achieve higher economic yields due to better material separation. Recyclability is determined primarily by the choice of materials (although this also depends on developments in the recycling industry) and the extent to which they

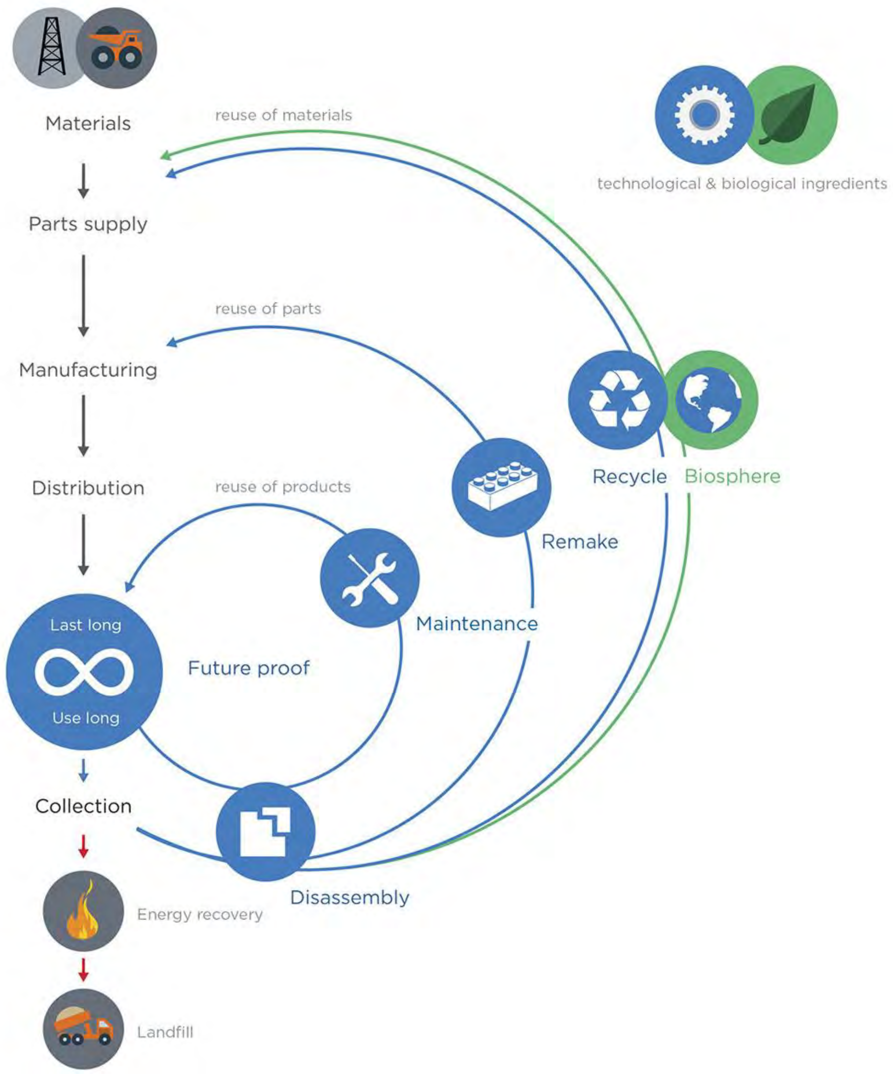

Figure 1. Circular product design model.

can be separated from each other. Electronic boards, given their high complexity and high materials value, pose a special case and should preferably be retrieved as an entity from the device.
The bio cycle with biological ingredients is simplified and placed next to the recycling circle. From a design perspective the ability to separate and recover materials is important.

Reuse is ill-defined, easily misunderstood and is therefore not used in the circular product design model. A recycling company and a second-hand shop both can talk about reuse, but will use the word in a completely different way. In the CE model every circle returns to an earlier point in the product life cycle, which is effectively the reuse of a product, component or material. Direct reuse by reselling/redistributing where a product is used for the same purpose without any changes is part of a business model and not that of product design, although such a business model will make longevity of products more attractive.

With the circular economy model adapted for product design and the derived five main topics a better understanding of criteria important to circular product design is obtained. Circular product design enables products that are future proof (last long and use long) and that can be disassembled, maintained (products), remade (components) and recycled (materials).

Vision
The circular product design vision (Figure 2) presents a quick overview of the five topics in their context. The tool could be used as a quick introduction, a discussion tool, a tool used in a workshop for a short design exercise or as a memory aid during the design process.

Figure 2. Circular product design vision.

Guidelines
The guideline list overview (Figure 3) groups and orders all relevant topics for circular product design. The extended list with guidelines from literature (Balkenende, Aerst, Occhionorelli, & van Meensel, 2011) (Desai & Mital, 2003) (Hata, Kato, & Kimura, 2001) (Hultgren, 2012) (Ijomah, McMahon, Hammond, & Newman, 2010) (Mital, Desai, Subramanian, & Mital, 2008) (Peeters, Vanegas, Dewulf, & Duflou, 2012) (Peeters & Dewulf, 2012) (Sundin, 2004) (Mulder, Basten, Jauregui Becker, Blok, Hoekstra, & Kokkeler, 2014) can be found in Appendix A. Disassembly is part of every circle and thus represented by a line on the left side extended downwards, divided in non-destructive and destructive disassembly. With the system approach of the CE model additional guidelines are included that are not part of DfX literature. Anticipating legislation could reduce the risk of not being allowed to use certain components or materials in the future. For example, legislation might be introduced to restrict the use of brominated flame retardants (Burridge, 2015) or to remove the PCB from

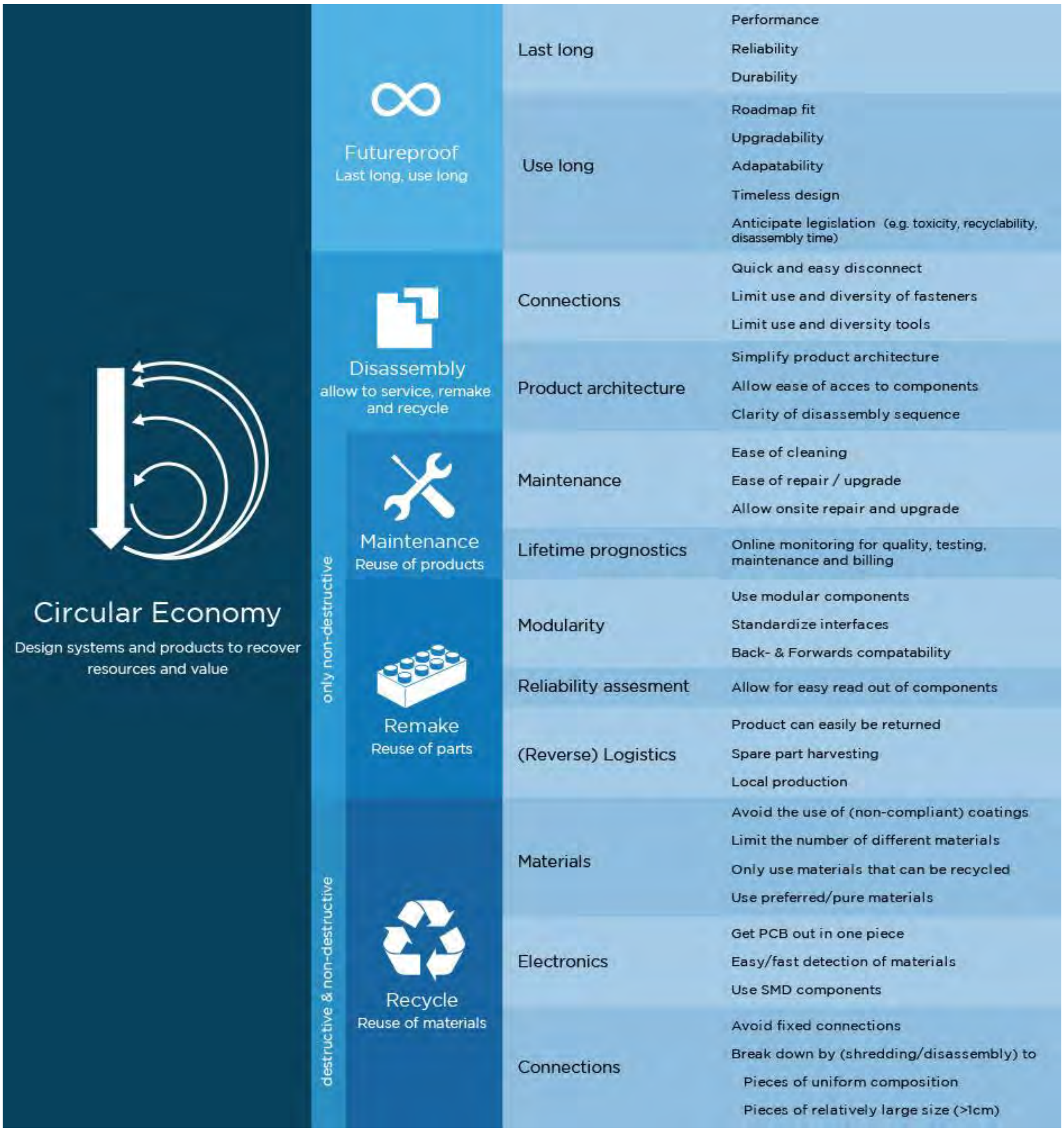

Figure3. Guideline list overview.

televisions by manual disassembly within 180 seconds (European Commission, 2012). The five main topics are further separated in sub-categories and sub-sub categories with respective guidelines.

Spider map

The guidelines can be translated into a spider map (Figure 4) for a more detailed tool to use in the design process. Words are placed along the axes to show an increase of circularity, i.e. describing aspects that are likely to aid in optimal resource usage and recovery. The tool can be used in the first phases of the design process when no detailed information is available yet. The spider map was tested in a workshop and design meeting with Philips employees (consisting of 3 product designers, 4 managers and 4 engineers, with different levels of CE knowledge). The Spider Map enabled the discussion of the ambitions for a new project, to show a way towards circular product design, to agree on terminology and to compare with other products. For example, the spider map was projected by a beamer and regularly referenced to during the workshop to discuss on which areas the product needs to be improved upon and to what degree. In contrast to a similar earlier workshop without the spider map there was more structure in the discussion and less time spent on defining the aspects that need to be taken into account for CE.

Concept design

The circular product design approach has been applied to the concept design of a B2B indoor luminaire (Figure 5 and 7). As a design exercise for testing and validating the framework the design goal was to design a luminaire that is optimally suited for a CE. The LEDs and driver are quick and easy to disassemble and accessible from underneath. This addresses one of the major limitations of

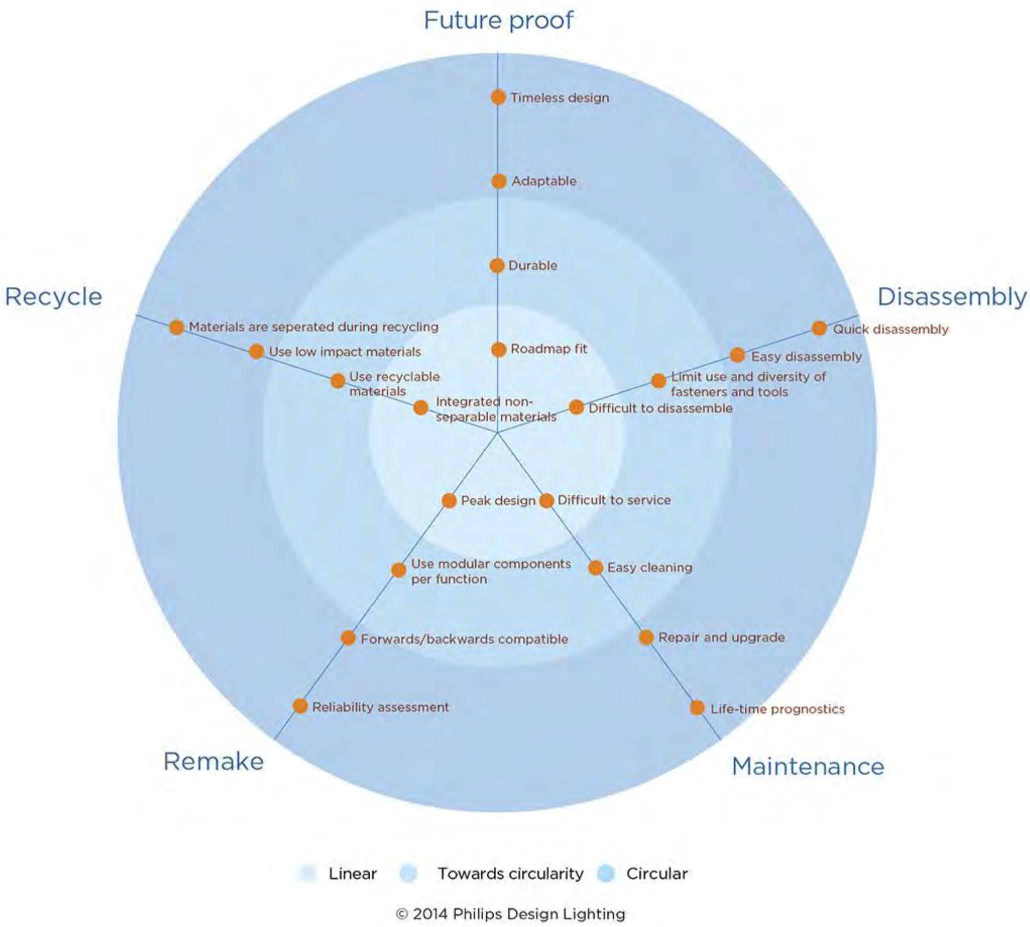

Figure 4. Spider map.

most B2B luminaires where LEDs are either non-replaceable or not in a cost-effective way. The driver includes power over Ethernet for life time prognostics. Both allow for improved maintenance. The modular approach benefits remake with the ease of access to all modules and allowing for easy reliability assessment. For recycling the same type of material is chosen for the backbone and housing, preferably aluminium for its high recyclability and, based on a quick estimation, relatively low impact. The electronics are easily separated by hand.

Initially, in the ideation phase, several product types were explored by going through each topic of Figure 2 while keeping in mind their relationship to each other by reading the sentences. Figure 1 continued to remind that towards the inner circle the most value is retained. For the highest chance of optimal resource use it made sense to take a systems approach by using a modular platform allowing a wide range of configurations and applications including retail, office and industry. This was mainly driven by Future Proof: what can increase the survival chance of a luminaire to be used long the most? This would need a shift from product to part obsolescence. The guideline list was primarily used after the ideation phase to see which guidelines could be further applied. The spider map has been used to verify the concept design was indeed better suited for a CE than several reference luminaires (Figure 6).

Conclusions
In this paper we outlined the exploration of circular economy from a product design perspective. A new understanding of circular design is presented, consisting of the following five main topics: future proof, disassembly, maintenance, remake and recycling. Three tools have been presented that aid the product designer in different ways. The circular design vision can be used for a quick-scan approach, the guidelines for detailed design and the spider map for comparing products and as a discussion tool with experts from other areas.

It should be noted, however, that the guideline list is not a list of independent parameters. For instance, an aspect like modularity is not only important to allow for remake, but also is enabling adaptability and upgradability (future proof) and maintenance. Furthermore, this research has focussed on the technological nutrient cycle and greatly simplified the biological cycle. Design guidelines for biological materials, if applicable, therefore are currently not present. In addition, note that these guidelines are not meant to be exhaustive.

The framework does not include renewable energy use. Product designers usually have no control over the choice of energy source (except for e.g. a built-in solar panel). The energy efficiency can be influenced, although that might be better suited as part of an ecodesign approach.

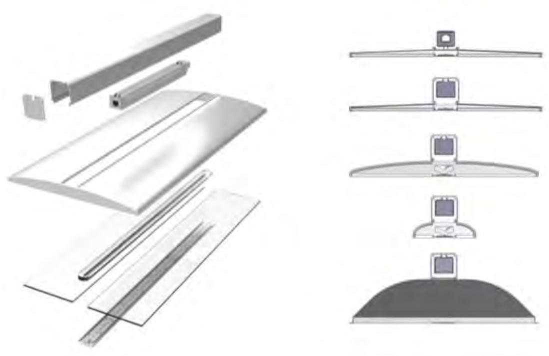

Figure 5. Concept luminaire.

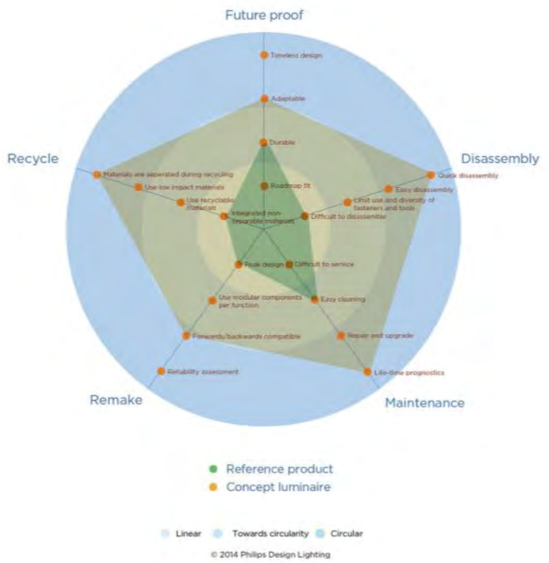

Figure 6. Score for concept luminaire and reference luminaire.

The spider map works well as a tool to show the degree of circularity and to compare between products. However, in the framework it gives the impression that all topics are

Figure 7. Application in office & industry

equally weighted and independent which is not entirely true. Recycling is the last option to recover any remaining value that a product or component has. This means that, in contrast to the other topics, recyclability is a mandatory requirement for every product. Placing recycling at top, using a different color or adding a subtitle might give recycling added importance. Further research and more case studies will be necessary for further testing and validation of the tools.

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Appendix A – Full guideline list

Category	Sub-category	Goal	Means	Source
Futureproof last long and use long	Long lasting	Performance		
		Reliability	Design out moving parts	(Mulder, et al. 2014)
			Design for under stressed use	(Mulder, et al. 2014)
			Provide redundancy	(Mulder, et al. 2014)
			Over dimension critical components	(Mulder, et al. 2014)
		Durability	Wear resistance	(Sundin, 2004)
			Use assembly methods that allow disassembly without damage to (reusable) components.	(Ijomah, et al., 2010)
			Do not use coated, painted or plated components	(Mulder, et al. 2014)
			Prevent discolouring	
			Ensure that fasteners' material are similar or compatible to that of base material thus limiting opportunity of damage to parts during disassembly.	(Ijomah, et al., 2010)
			Aging and corrosive material combinations need to be avoided, since disassembling them cleanly and efficiently (due to their tendency to corrode, spread corrosion, and break off inside the product) often is difficult.	(Mital, et al., 2008)
			Protect subassemblies from corrosion, the reasons being the same	(Mital, et al., 2008)
	Long in use	Roadmap fit	Ensure a long -term roadmap is available	
		Upgradability	Use materials and assembly methods that do not prevent upgrade and rebuilding of the product.	(Ijomah, et al., 2010)
			Structure to facilitate ease of upgrade of product.	

		Adaptability	Ensure a long -term roadmap is available	(Ijomah, et al., 2010)			
			Prevent product obsolescence (user needs)	van den Berg			
		Timeless design	Emotional durable design (user desire)				
		Anticipate legislation	(e.g. toxicity, recyclability, disassembly time)				
Disassembly non-destructive	Connections	Quick and easy disconnect	Use easy to disassemble connections				
			Apply loose fits for internal components	(Peeters, et al., 2012)			
			Avoid welding and adhesive between sub-assemblies	(Ijomah, et al., 2010)			
			Use joining methods that allow disassembly at least to the point that internal components and subsystems requiring it can be accessed for testing before and after refurbishment.	(Ijomah, et al., 2010)			
		Limit use and diversity of fasteners	Minimize the number of fasteners used in an assembly	(Mital, et al., 2008)	(Peeters, et al., 2012)	(Ijomah, et al., 2010)	(Balkenende, et al., 2011)
			Minimize the types of fasteners used in an assembly and standardize the fasteners used	(Peeters, et al., 2012)	(Ijomah, et al., 2010)	(Balkenende, et al., 2011)	
			Fasteners need to be easy to remove or destroy.	(Mital, et al., 2008)			
			Allow easy access and identification of the fasteners	(Mital, et al., 2008)	(Sundin, 2004)	(Ijomah, et al., 2010)	(Balkenende, et al., 2011)
			Consider the use of fasteners incorporating an active disassembly or embedded disassembly functionality.	(Balkenende, et al., 2011)			
		Limit use and diversity of tools	Limit the number of tools needed and tool changes	(Balkenende, et al., 2011)			
			Make it possible to use simple tools for disassembly	(Balkenende, et al., 2011)			
	Product architecture	Simplify product architecture	Minimize the complexity of the product structure	(Desai & Mital, 2003)	(Ijomah, et al., 2010)		
			Select a product structure which allows a sequence independent disassembly	(Balkenende, et al., 2011)			
			Minimize the number of components used in an assembly	(Mital, et al., 2008)	(Desai & Mital, 2003)	(Ijomah, et al., 2010)	(Balkenende, et al., 2011)

			Optimizing the spatial alignment between various components to facilitate disassembly without jeopardizing assemblability,	(Desai & Mital, 2003)		
			At least one surface needs to be left available for grasping.	(Mital, et al., 2008)	(Sundin, 2004)	
			Simplify and standardize component fits	(Ijomah, et al., 2010)		
		Ease of access to components	Arrange components for ease of disassembly	(Ijomah, et al., 2010)	(Balkenende, et al., 2011)	
			Consider making the plane of access to components the same for all components	(Mital, et al., 2008)	(Sundin, 2004)	(Balkenende, et al., 2011)
			Avoid the need to turn the product in the disassembly process	(Mital, et al., 2008)	(Sundin, 2004)	(Balkenende, et al., 2011)
			Metal inserts in plastic parts should be avoided, since this increases material variety and part complexity and necessitates multiple directions and complex movements in disassembly. Applicable if meant for over moulding	(Mital, et al., 2008)		
			Use assembly methods that would allow disassembly at least to the point that internal components and subsystems requiring work can be accessed.	(Ijomah, et al., 2010)		
		Clarity of disassembly sequence	Identify components assembly sequence.	(Ijomah, et al., 2010)	(Sundin, 2004)	
			Identify components requiring similar assembly tools and techniques.	(Ijomah, et al., 2010)	(Sundin, 2004)	
			Reduce complexity of reassembly	(Ijomah, et al., 2010)		
Maintenanc	Maintenance	Ease of cleaning	Ensure product surfaces are smooth and wear resistant.	(Ijomah, et al., 2010)		
			Ensure that all parts to be cleaned are easily accessed.	(Ijomah, et al., 2010)	(Peeters, et al., 2012)	(Sundin, 2004)
			Use material that would survive cleaning process e.g. ensure that material melting	(Ijomah, et al., 2010)		

	e Reuse of products			point is higher than clean process temperature.			
				Limit the number of material types per part.	(Ijomah, et al., 2010)		
				Identify components requiring similar cleaning procedures and cleaning agents.	(Ijomah, et al., 2010)	(Sundin, 2004)	
			Ease of repair	Allow for easy and quick access to parts prone to failure	(Peeters, et al., 2012)	(Ijomah, et al., 2010)	(Sundin, 2004)
				Avoid assembling components with a different life duration	(Balkenende, et al., 2011)		
			Allow onsite repair and upgrade	Allow on-site maintenance			
		Lifetime prognostics	(Online) monitoring for quality, testing, maintenance and billing				
non-destructive	 **Remake** Reuse of components	Modularity	Use modular components	Use modular structure so that obsolescence occurs with components rather than with entire product.	(Ijomah, et al., 2010)	(Mital, et al., 2008)	(Ijomah, et al., 2010)
				Do not combine components that have different physical life.	(Hata, et al., 2001)		
				Do not combine components that have different intervals for maintenance and upgrade.	(Hata, et al., 2001)		
				Group components in sub-assemblies according to reuse, reconditioning or remanufacturing potential	(Balkenende, et al., 2011)		
				Concentrate compatible material groups in separate subassemblies of a product	(Mital, et al., 2008)	(Balkenende, et al., 2011)	(Hata, et al., 2001)
				Allow customization by grouping components in liberally	(Balkenende, et al., 2011)		
				Combinable subassemblies	(Balkenende, et al., 2011)		
			Use standard interfaces	Standardize parts	(Ijomah, et al., 2010)		
				Standardize interfaces	Maarten		

			Back- & forwards compatibility		Nestor Palma		
		Reliability assessment	Allow for easy testing of components	Standardize test procedures	(Ijomah, et al., 2010)		
				Structure for ease in determining component condition	(Ijomah, et al., 2010)	(Sundin, 2004)	
				Structure so testing is sequential, mirroring reassembly order	(Ijomah, et al., 2010)		
				Minimize the disassembly level required to effectively test components	(Ijomah, et al., 2010)		
				Clearly identify component load limits, tolerances and adjustments	(Ijomah, et al., 2010)	(Sundin, 2004)	
		(Reverse) logistics	Product can easily be returned	Ensure products can be stacked			
				Ensure products can safely be transported			
				Minimize product volume			
			Allow for spare part harvesting				
			Local production				
non-destructive & destructive	**Recycling** Reuse of material	Materials	Avoid the use of (non-compliant) coatings	Any secondary coating processes, such as painting, are to be avoided, since they inhibit access to and removal of components	(Balkenende, et al., 2011)	(Mital, et al., 2008)	(Hultgren, 2012)
			Limit the number of different materials	Minimize the number of material types used in an assembly	(Balkenende, et al., 2011)	(Ijomah, et al., 2010)	(Hultgren, 2012)
			Only use recyclable materials		(Balkenende, et al., 2011)	(Hultgren, 2012)	
			Use preferred/pure materials	Increase the use of common materials	(Balkenende, et al., 2011)	(Desai & Mital, 2003)	
			Allow material separability	Consider the material compatibilities to eliminate the need of separation for recycling	(Balkenende, et al., 2011)		
				Allow easy material identification	(Balkenende, et al., 2011)	(Mital, et al., 2008)	(Sundin, 2004)
				Add non-contamination markings for the ease of sorting and recycling	(Balkenende, et al., 2011)	(Mital, et al., 2008)	

				Any harmful materials, if functionally important, should be grouped together into subassemblies for fast disposal.	(Balkenende, et al., 2011)	(Mital, et al., 2008)
				Do not use fasteners that are not compatible with the connecting components. Fasteners are recycled together with the host component; therefore choose plastic fasteners for plastic and metal fasteners for metal to avoid polluting other material streams or end up in the waste fraction	(Hultgren, 2012)	
		Electronics	Get PCB out in one piece		(Balkenende, et al., 2011)	
			Easy/fast detection of materials		(Balkenende, et al., 2011)	
			Use SMD components		(Balkenende, et al., 2011)	
		Connections	Avoid fixed connections	Prefer snap-fits for plastic components (particularly housing), to allow easy liberation of materials	(Balkenende, et al., 2011)	(Hultgren, 2012)
				Use a detachable power cord instead of a permanently fixed one	(Hultgren, 2012)	
			Break down by (shredding/disassembly) to	If connections are applied that enclose materials permanently, apply gaps and or break-lines to the enclosing material to enable liberation during shredding	(Balkenende, et al., 2011)	(Hultgren, 2012)
			Pieces of uniform composition		(Balkenende, et al., 2011)	
			Pieces of relatively large size (>1cm)		(Balkenende, et al., 2011)	

Development of a whole system design tool for business model innovation towards a circular economy

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Keywords: sustainable design, complexity, whole system design, business models, circular economy.

Abstract: As a response to increasing resource constraints and price volatility many organisations are investigating new circular business models, which re-examine a product's value across multiple lifetimes. One of the many challenges faced is the integration of key stakeholder perspectives across a company's broad value network for the impact of change to be fully visualised.

Whole System Design (WSD) has been identified as an appropriate methodology to address sustainable business models. However there is currently a lack of guidance for companies wishing to adopt such an approach. This research aims to define a WSD tool, which will enable business to effectively evaluate product and service innovations for a circular economy. The tool will demonstrate the relative importance of flows in resource, and support the identification of a company's stakeholder network in order to understand how business models may change as maintenance, re-use, remanufacture and recycling are investigated.

The tool, presented within this paper, comprises of a card game played in three stages. Stage one identifies the existing business system, stage two clarifies hazards and opportunities and stage three reveals circular innovations relevant to the business value network. In addition to written data collected using the tool, video recordings and a qualitative questionnaire are also used to incorporate participant's responses and post interview reflections relevant to the research criteria. Findings of the research contribute valuable insight, including the importance of WSD in addressing complexity inherent in circular business models and the requirement highlighted by literature for a workable WSD tool.

Introduction

Declining product longevity is contributing to dramatic increases in resource demand and yet our world's natural resources remain finite. Our current "take-make-dispose" economy is largely linear with a reported 80% of mined or harvested products ending up in landfill within only a couple of years of sale to consumers (Inglethorpe, 2013). This wastage must change if we are to guarantee continuing prosperity for future generations. Companies can benefit by targeting resource productivity through the development of products, which either endure or are restorative by design. This is the concept of a Circular Economy (CE), where waste can be reinvested as resource for future products and services (Ellen MacArthur Foundation, 2013).

A key challenge for developing CE business models is "the cognitive limits of human ingenuity in the face of complex dynamics and the associated failure to anticipate unexpected consequences of innovation" (Westley *et al.*, 2011, p. 774). Designers and managers considering product longevity must therefore take a whole system view to ensure innovations provide long term value not only for the consumer but also for the manufacturer and its supply chain. To address the challenge, this research describes the development of a new Whole System Design tool that enables a variety of business stakeholders to take a systemic view of their company in order to explore transition to CE.

Background

Strategies for product life extension

There is a lack of willingness within industry to design with consideration for product life extension. Recent reports have highlighted a significant increase in the volume of complex electrical waste being sent to landfill (UNEP, 2010). Products within these waste streams contain a variety of metals, plastics, glass and ceramics, often bonded together in complex assemblies. A lack of consideration for disassembly or future recycling in the design of these products often results in inefficient methods of recycling which may also pose a risk to health and environment (UNEP, 2013).

Research by Bakker *et al.*, (2014) aims to identify the optimal lifespan for certain electronic products. Findings suggest that the definition of "optimal life" will vary significantly for products according to how they are used. If we consider environmental impact, recent improvements in energy efficiency for products have not been sufficient to offset the negative impact of declining product life spans. Consumer groups have begun to react against planned obsolescence, using Repair Cafes and Hackerspaces to fix their broken electrical products (Charter & Keiller, 2014). Some traditional recycling companies have also taken interest in the refurbishment and re-use of products as a growing revenue stream.

However, these activities are primarily reactive to the waste problem and do not address the redesign and remarketing opportunity for mass manufacturers and global brands. Bocken *et al.*'s (2014a) review of literature around sustainable business has identified eight business model archetypes which can be further explored to achieve product sustainability; four are complimentary to the field of product life extension "Creating value from waste", "Maximising material and energy efficiency", "Delivering functionality rather than ownership" and "Encouraging sufficiency".

Baines *et al.* (2007) highlight successful examples of Product Service Systems (PSS): the sale of "product use" versus "product ownership", such as Electrolux's pay-per-wash washing machines and Mobility of Switzerland's car sharing scheme. Companies considering a transition to PSS must, however, address consumer uncertainties highlighted by Catulli (2012) such as warranty, maintenance, product upgrade and delivery. Clearly companies considering PSS must also consider the consumer service relationship in addition to design for improved durability and serviceability.

One key goal for PSS and other business models aiming to achieve product life extension is to achieve an enduring brand relationship with the end user. Such services offer opportunities to revisit the user and provide additional valued services to address consumer uncertainties. Service innovation is therefore one of the key opportunities (and challenges) in moving to CE.

A reflection on existing ecodesign tools

Many ecodesign tools have been identified to aid the development of sustainable products. However, a taxonomy of this field by Bovea and Perez-Belis (2011) highlights that these tools often consider the environmental aspect of a product in isolation without due consideration for the ongoing design process. Their paper aims to facilitate the integration of these tools but little mention is made of service design, user experience or brand values - all are key considerations in the development of how a product or service is delivered to the customer.

Other papers identify the importance of "system" or "holistic" tools in providing a wider view of the complete life cycle for a product. Many designers struggle with the specialist skills required to deliver a full life cycle assessment (LCA). Vogtlander (2010) acknowledges that the LCA process may have become needlessly complex with the use of sophisticated software and specialist jargon. Such software requires that designs are mostly complete and material or energy data are clear - this is impractical when environmental impacts are best minimised at the Front End of Eco-Innovation (Bocken *et al.*, 2014b).

The importance of business model innovation

Considering a holistic view, Boons and Ludeke-Freund (2013, p. 17) describe how business models require a systemic perspective built "from the viewpoint of how the firm can connect to, or build up, that system while delivering a certain value proposition" as ultimately "without a successful diffusion in society, eco-innovations are meaningless" (Boons & Ludeke-Freund, 2013, p. 11). Businesses exploring innovation through a circular value chain are further challenged because "the scope of the business model is both broader and more complex than in the traditional linear model" (Roos, 2014, p. 267).

Addressing complexity, Boons *et al.*, (2012) highlight the importance of stakeholders in sustainable business models. A stakeholder may be "any group or individual who can affect or is affected by the achievement of the organisation's objectives" (Freeman, 1984, p. 46). This may describe internal employees or outside collaborators; each has crucial insight into value generation.

Exploring the whole system

Whole system design is a technique of collaboration defined thus:

> *"(WSD) considers an entire system as a whole from multiple perspectives to understand how its parts can work together as a system to create synergies and solve multiple design problems simultaneously. It is an interdisciplinary, collaborative, and iterative process"* (Blizzard & Klotz, 2012, p. 458).

WSD as a field of practice remains young and literature defining the technique is also limited. Research by Coley and Lemon (2009) highlights the collaboration of multiple stakeholders as essential to holistic solutions. Charnley *et al.*, (2010) define 10 common themes for the process including the requirement for trans-disciplinary skills, necessity for actors to develop shared purpose, and development of cohesive teamwork through mutual understanding. Blizzard and Klotz (2012) acknowledge that workable WSD tools for designers and business planners are as yet undefined.

This paper aims to address the gap by defining a WSD tool, which is effective for a wide variety of businesses in evaluation of innovation projects for CE.

Criteria for the tool

In consideration of the WSD tool development, the literature review above has highlighted five key criteria. The tool must:-

a) Address the breadth and complexity required for a systematic approach to circular business models by revealing the complete framework of the organisation (Roos, 2014).

b) Provide a systemic view of the business, which (unlike current LCA) everyone can understand (Vogtlander, 2010), highlighting key materials and energy flows including human capital.

c) Be an educational tool, encouraging cross-disciplinary learning and mutual understanding (Charnley *et al.*, 2010).

d) Encourage exploration of service innovations for CE such as product service systems (Baines *et al.*, 2007).

e) The tool should demonstrate how firms can connect to, or build a value proposition during transition from linear to circular business models (Boons and Ludeke-Freund, 2013).

Methodology

Tool Development

A formal workshop with 40 experts from the CE field was held with the aim of identifying a suitable methodology for addressing the above criteria. Various existing tools were evaluated which aim for broader adoption by business of CE principles. The review highlighted the need for a tool to encourage participation across many individuals within an organisation from CEO to Janitor, regardless of experience. The concept identified with most potential was the idea of a "toy or game" to be played with an individual or group of people.

In order to deliver WSD criteria a card game was developed based upon three stages of interaction. Firstly a series of cards to clarify the existing business model, next a set of cards which highlight threats, opportunities and ideas, then finally a third set of cards highlighting CE innovation opportunities. A small UK-based sustainable furniture business was chosen for the first case study. The activities and structure of the business were examined and stakeholders across the business enlisted for one-on-one interviews and game play.

Research method for primary case study interviews

A qualitative approach was selected for the research in order to explore individual perceptions of processes throughout the company (Robson, 2002). Each interview took between 45-90 minutes and was conducted over a large table so that game cards could be clearly spread out. Interviews were recorded using video and at the end of each interview photos were taken detailing each individual's system map. All memo notes attached to cards during the game were collected and transposed into a spreadsheet.

Card Design

Card designs are shown below (Figure 1) and arranged according to the three stages described.

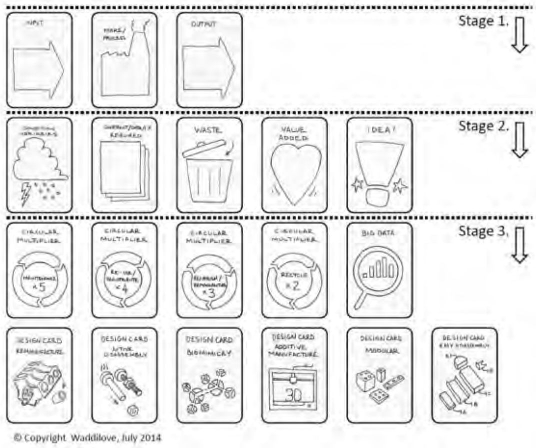

Figure 1. Card design summary.

Card Game Procedure

Before the game began, participants were asked to focus on an existing company product as a theme for the card game.

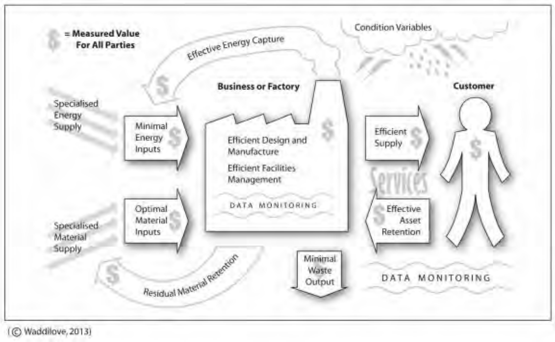

Figure 2. Introduction to the theme for the game

Players were shown the diagram in Figure 2 which summarises subjects revealed during the game. Each interviewee was asked to describe their personal view of the company system as it related to the product in question.

Each player was handed a selection of memo note pads in various colours along with a black pen. Players followed the 'Game Instructions' shown in Figure 3 and memo notes were added to each input card as it was placed on the table.

Stage / Card Type	Required Equipment: Card Pack, Memo Notes (various colours), Marker Pen, Video Camera, Tripod
Pre-Interview	Request: Please select a product offered by your company which we will use as the focus for research questions during this activity
Stage One	**Question Prompt**
Input	Please use the memo pad provided to describe all inputs to your business (Eg. Raw Materials, Components, Energy, Labour)
Make/Process	Describe all processes that occur within your business to create the product (Eg. Design, Assembly, Testing, QA, Packaging)
Output	Describe outputs: What leaves the factory, what is your brand/service offering (Eg. Product, Differentiation, Sales Route, Online Service)
Stage Two	**Question Prompt**
Condition Variables	Review your system map. Highlight condition variables affecting your business (Eg. Price Variation, Material Availability)
Contract/Data/I.P.	Highlight areas of the business where legal documents may be required (Eg. Design Patents, Supplier/Customer Contracts, Warranty)
Waste	Describe any waste that currently exists within your system (Eg. Material Offcuts, Energy, Human Activity, End-of-Life Packaging)
Value Added	Describe the value added for your external clients/suppliers/customer and internal employees (Eg. Brand, Design, Reliability)
Idea!	Pause and review your whole system including stage two cards - Add any new ideas that have come to mind during the process
Stage Three	**Question Prompt**
Circular Multiplier Maintenance x5 Re-Use x4 Refurbishment x3 Recycling x2	These are your Circular Multiplier Cards. They allow you to add value to areas of your business using the Circular Economy approach highlighted in our introduction. You will notice the cards include a multiplication value, this is based upon published research demonstrating that higher value can be achieved though "inner circle" activities such as maintenance. Try to use more than one multiplier card and also identify projects in different areas of your map (Eg. Input, Process, Output)
Big Data	Now identify areas of your business which could benefit from I.T. Infrastructure with a focus on Big Data
Design Cards Remanufacture Biomimicry Active Disassembly Easy Disassembly Modular	These are your Design Cards. They help you to identify design activities which may help with the execution of innovation projects defined during this process. Please select any cards which you think will be useful and place them next to the area of the system map where they would apply. Use muliple cards if required and also aim to identify projects in different areas of your map which may benefit (Eg. Input, Process, Output)
Conclusion	Your system map is now complete. Please take time to review and identify which projects have the most value for your business.

Figure 3. Player instructions for whole system innovation card game.

On completion of level one the underlying system of the current business becomes clear. Players then proceeded through stage two and then on to complete stage three where CE innovations are finally identified.

Research Method for Round Two

Once the primary case study was completed for a simple UK business a second round of research interviews were undertaken with 12 companies to test the tool with complex, international businesses. In addition to using the tool itself, participants were asked a series of 10 questions as a "post intervention interview to help incorporate the participant's perspective into the findings" Robson (2002, p. 270).

Qualitative questions used during round two resulted in three new card designs proposed by various players to address missing parts of the process. First, a "Reverse Logistics" card to help players consider how materials and products might cycle back to factories or suppliers. Second, a "Partnerships & Collaborations" card so that partners could be named for specific projects. Third, a new Design Card "Material Science" to help designers suggest new materials or developing technologies.

Research findings

Primary case study: Fluteoffice

Fluteoffice is a UK based manufacturer and marketer of 100% sustainable cardboard furniture for the workplace. Their FlutePRO desk is designed to be taken back, re-used, re-cycled, up-cycled or re-manufactured. As such, it is a useful example of a sustainable business already exploring CE innovation. Initial interviews at Fluteoffice were held with five different stakeholders, summarised below in Figure 4:

Position	Location	Staff level
Strategic Advisor - Brand & Media	Cambridge	Consultant
Office Manager	Surrey	Staff
CEO	Surrey	Co-Founder
Design Director	Surrey	Co-Founder
Production Liason / Delivery Driver	Surrey	Staff

Figure 4. Summary of Fluteoffice employees participating in first round.

Interviewees were challenged to describe subjects outside the main focus for their job. The game's systemic approach was useful in meeting this objective however this was also a small company where employees are encouraged to "multi-task".

Thematic analysis (Braun & Clarke, 2006) was carried out on comments recorded during primary case study interviews. Figure 5 shows key insights using a three column chart to demonstrate how each stage of the research builds. Common themes across multiple interviews lead to tangible challenges which either directly or indirectly reflected the ideas generated.

Common Themes -->	Challenges Identified -->	New Ideas Generated
Input - Raw Materials (cardboard, glue)	Material price & availability	Seek alternate products / materials
Input - People (staff, employees)	Staff health & happiness (retention)	Less travel / More home working
Input - Energy (light, heat, fuel)		
Process - Making desk (cut, fold, glue, print)		
Process - Design / I.T. (CAD, brand, comms.)	Data requirement to meet company & CSR goals	Use big data for asset register, location, use, cond.
Process - Transport	Variable transport costs	I.T. Infrastructure - Better stock control system
Process - Cut to size & shape	Delivery packaging currently waste	Customised, reusable packaging for transport
Output - Sustainable desk	Customers old furniture currently waste	Convert customer waste to value items
Output - "Pay per Use" service	Ongoing funding stream	
Output - Take back service for reuse and reman.	Performance of business model vs behaviour	Partnerships required - Small player in huge industry
Waste - Energy		
Waste - Offcuts		
Waste - Staff time	Time wasted looking into projects that don't happen	
Contracts - Patents for R&D		
Contracts - Key suppliers & customers	Client understanding of new business model	Deeper discussion required with suppliers & customers
Condition Variable - Competition	Capacity to scale up business	Become well known as a pioneer in this field
Condition Variable - Quality	Quality	New premisis - All processes under one roof

Figure 5. Thematic analysis of memo notes from primary case study.

Secondary case study: relevance to industry

For the second round it was important to examine a variety of products and organisations. (Figure 6.) In some cases the product was more complex, including a variety of materials and components, and elsewhere the business relied upon manufacturing or raw materials from distant countries. Many companies in this round were far reaching international brands with comprehensive product lines.

Name	Industry	Participant Role
Company 'A'	Global High Volume Consumer Electricals	Product Stewardship Manager (+1 staff)
Company 'B'	Global High Volume Consumer Electricals	US Design Team (5 select staff)
Company 'C'	Global High Volume Consumer Electricals	Environmental Program Manager
Company 'D'	Global Printers & Document Management	Head of Corporate Social Responsibility
Company 'E'	Global Premium Coffee & Coffee Machines	Sustainability Program Manager
Company 'F'	Global Diversified Technology Company	Program Manager Circular Economy
Company 'G'	UK Non-Profit Recycling Advocate	Special Advisor for Business Models & Electricals
Company 'H'	Global Furniture Retailer	Sustainability Developer
Company 'I'	Multinational Home Improvement Retailer	Head of Net Positive Delivery
Company 'J'	Clothing Division of Global Supermarket Retailer	Corporate Responsibility Manager (+2 staff)
Company 'K'	UK Cancer Charity with High Street Retail Outlets	Acquisitions Manager (+2 staff)
Company 'L'	UK Circular Economy Charity with Global Partners	Various (8 select staff)

Figure 6. Summary of 12 companies participating in second round.

Further thematic analysis was carried out on data collected during this second round. Each video interview was transcribed to record relevant comments based upon identified tool criteria (Robson 2002). Qualitative questioning generated a variety of insights relevant to the original tool criteria:-

a) **Understanding breadth and complexity.** Cards gradually build system complexity, challenging interviewees to think beyond their normal scope of work. One interviewee stated, "It has opened my mind to considering parts of the process that I hadn't previously identified as an opportunity before."

b) **Provide an easily understandable systemic view.** Simple pictures and text make the cards approachable for all employees. One team noted "It's accessible by people at different levels of the organisation."

c) **An educational tool for cross-disciplinary learning.** The WSD tool was proven to encourage collaboration and education between different stakeholders. One designer said "With a tool like this we could talk executives through the reasoning for initiatives." Another external business partner stated "Helps us to understand each other's processes and to stop thinking in a linear process."

d) **Exploration of service innovations for CE.** Various interviewees highlighted that the tool was particularly useful for exploring service innovations. One commented directly "It works well for service!" and another explained "If you've got a product that has significant enduring value you can keep going at the right side of the system map."

e) **Building value during transition from linear to circular.** As the game unfolds people can see the value in a transition to CE. One participant summarised as follows "What's good is it's not theoretical... It's where we are now and what practical steps can be taken toward the goal of a circular economy."

Discussion

The intention of this research was to define a WSD tool, which is effective for business in evaluation of innovation projects for CE. One challenge is to enable a clear systemic view, as business models within CE will potentially be more complex. However, complexity is necessary in discovering value for materials and energy flows throughout a company system. Modern computer technology enables fine filtering of systemic business value to enable measurement of 'total value throughout life' for each product created. In a future circular economy the measurement of enduring value is an essential counterpoint to highlighting the futility of waste.

If we reflect on interviews where the tool was successful, it appears that the three stages play an important role in identifying opportunities for change. Innovations identified during stage three were grouped around business challenges identified in stage two. This observation links to studies around diffusion of innovations by Geels (2004) where opportunity niches play a vital role as seeds for business transformation.

Interviews in the second round highlighted the value of this WSD tool in considering the international perspective for CE. In a global marketplace, I.T. infrastructure for big data plays an important role in the accurate valorisation of business opportunities. Companies who benefit most from CE will be those with significant influence over their whole supply and service system.

Conclusions

This research contributes valuable insight for two fields of interest. Firstly, research addresses the requirement highlighted by Blizzard and Klotz (2012) for a workable WSD tool. The innovation card game was originally intended for product development teams, however companies in the second round have also demonstrated value for service innovation, highlighting the tools adaptability. The card tool is particularly beneficial in aiding the transition to CE as it enables participants to think non-linearly whilst building new circular innovations upon the foundations of an existing business framework. The tool also enables individuals interested in sustainable design to explore system-wide opportunities for transition to innovation models based upon CE.

Secondly, business leaders can benefit from a methodology, which helps to address the complexity challenge highlighted by Roos (2014) for companies in transition to CE business models. The three stage approach of this WSD tool demonstrates how business challenges often provide the seeds for change in any organisation through identification of opportunity niches as defined in Geels' (2004) work on diffusion of innovations. Future developments of the tool must be data-rich whilst also highlighting business value, key deliverables and ownership in order to ensure successful implementation of circular projects.

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ELLEN MACARTHUR FOUNDATION
Rethink the future

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The consumers' desired and expected product lifetimes

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Keywords: product use-time; desired lifetime; expectations; replacement decisions; survey.

Abstract: In this paper, we present empirical evidence from a large-scale questionnaire survey on the average use-times of durable goods and the consumers' desired lifetimes. The results show that consumers' want durable goods to last between 1.7 and 3.6 times longer than they are used. Moreover, we emphasise the difference between desired and expected lifetimes and explain, how the consumers' expectations regarding product lifetimes affect their buying and replacement decisions.

Introduction

Modern society witnesses an unprecedented acceleration of social life (see Rosa, 2015). This can also be observed for contemporary material and consumer culture, which is characterised by increasing product replacement rates and short product life spans. As a result of this development, overall resource consumption reached a level that severely harms the environment and threatens the well-being of future generations. Moreover, increasing replacement rates create social pressures to stay up to date and keep pace with the technological development, resulting in harried and exhausted consumers. In light of these adverse consequences of fast consumerism, various observers called for a deceleration of consumption (Ax, 2001; Cooper, 2005).

However, surprisingly little is known about the motivations behind replacement decisions and empirical evidence on the actual replacement rate of consumer durables remains rare.1 Most evidence is limited to single products like cars, washing machines and mobile phones. Another limitation is that the data lacks comparability due to conceptual confusion and different approaches to measurement. To bring some conceptual clarity into the debate, we thus decided to introduce a useful term from German. The "use-time" (German: Nutzungsdauer) denotes how long a product is used and includes both the duration in operation and the duration in stand-by (Murakami, Oguchi, Tasaki, Daigo, & Hashimoto, 2010). The use-time is thus formulated from the perspective of the user instead of the product. Correspondingly, we suggest to use common terms like product lifespan, lifetime and service life from a products' perspective only.

In this paper, we provide empirical evidence from a large-scale questionnaire survey on the average use-times of 21 products, including cars, clothes, consumer electronics, small and major household appliances, and furniture. Furthermore, we draw from 25 interviews with Austrian residents to show how product use-times and replacement decisions are related to the consumers' expectations regarding product lifetimes. This study thus contributes to the discussion on replacement motivations and addresses calls for evidence beyond single product categories (Cox, Griffith, Giorgi, & King, 2013; Evans & Cooper, 2010).

Methods and sample

The empirical material comprises two sources of data: The first one is a web-based, large-scale questionnaire survey that was sent out to appr. 5,600 Austrian residents in November, 2014. Within two weeks, we received 1,009 completed questionnaires (response rate: 18%). The final sample is representative for the Austrian population aged between 18 and 65 in

[1] See Wieser & Tröger (2015) for an overview of empirical evidence.

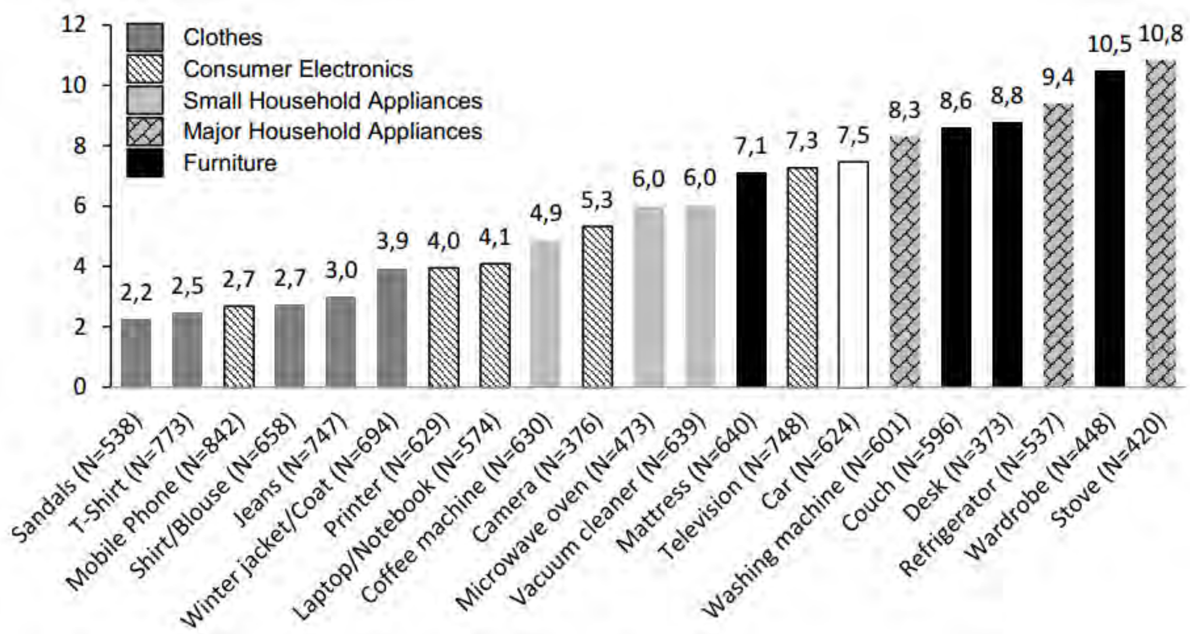

Figure 1. How long do you normally use the following products before storing, passing on or discarding them (in years and months)?

terms of gender, age, education, household structure, and region (see appendix).

Before we sent out the questionnaire, it was cognitively pre-tested among nine participants using probing and paraphrasing techniques (see Collins, 2003).

The second data source is derived from 25 semi-structured interviews conducted in the period between January and March 2015. The interviews followed a guideline and took 95 minutes on average. The first half of the interviews inquired about the “careers” (i.e. past experiences) of the interviewees as users of mobile phones. The second half was concerned with the living situation and focused on items like major household appliances and furniture. The design of the interview guideline was inspired by practice research (see Røpke, 2009; Warde, 2005).

The interviewees were obtained via the questionnaire survey, in which we asked respondents to indicate their willingness to participate in a follow-up study. [2] The final sample was fairly balanced in terms of gender, age, household composition, and housing situation. Finally, the interviews were fully transcribed and coded.

Results

The questionnaire survey inquired about the use-time of various products. This required two steps: First, respondents had to go through a list of 21 products and indicate which they have already possessed and discarded or replaced. We selected at least three durable goods from five product categories: clothes, consumer electronics, small household appliances, major household appliances, and furniture. Moreover, we added the car because of the high environmental potential associated with an extension of its average use-time. The dissemination of the selected goods ranges from 37% (desk and camera) to 83% (mobile phone). Only 8.6% of the respondents have already possessed all 21 goods. In a second step, respondents were asked to indicate how long they typically use the selected products before storing, passing on or discarding them (in years and months).

Figure 1 depicts the average use-time of each product.3 The lowest use-times are found for clothes, which are used between 2.2 (sandals) and 3.9 years (winter jacket/coat) on average. Being used for only 2.7 years, mobile phones clearly stand out among consumer electronics. In terms of differences between socio-

[2] The design of the participant selection procedure made sure that the participants' anonymity was not compromised

[3] See Wieser & Tröger (2015) for details and explanations of these relationships.

demographic groups, we find strong, positive relationships between the respondents' age and the use-times of most products. Although less pronounced, also income, and educational level are positively related to longer use-times. Moreover, use-times are negatively related to household size.

Intriguingly, the use-times obtained in this study are significantly shorter than the ones reported in recent studies conducted in Spain (Gutíerrez, Adenso-Díaz, Lozano & González-Torre, 2011) and Germany (Prakash, Dehoust, Gsell & Schleicher, 2015). In comparison with the use-times reported in the latter study, the differences amount to 3.6 years for washing machines, 3.9 years for refrigerators, three years for stoves and 2.9 years for TVs. A recent study from Brazil, however, yielded similar use-times as reported here (Echegaray, 2014).

Figure 2 illustrates how long consumers would like products to last (i.e. 'desired lifetimes'). Notably, consumers want products to last considerably longer than they are currently used. A summary of the ratios between actual use-times and desired lifetimes can be found in Table 1.

The desired lifetimes, however, should not be conflated with the people's expectations regarding product lifetimes. Our interviews show that people generally assume that products will last considerably shorter than they would like them to last. For instance, one interviewee stated: “I want a washing machine to last 10 years, but expect 5 years”. With the notable exceptions of Knight, King, Steffen & Cox (2013) and Wilhelm, Yankov & Magee (2011), this difference was not taken into account in previous studies. Cooper (2004), Brook Lyndhurst (2011) and Echegaray (2014), for instance, asked their respondents to indicate a 'reasonable' lifespan of various products and interpreted the results as desired lifetimes. A 'reasonable' lifespan, however, can also reflect the respondents' assumptions or expectations regarding product lifetimes. Consequently, previous studies underestimated the difference between desired lifetimes and use-times.

Differentiating between desired and expected lifetimes proves also important for a better understanding of the consumers' buying and replacement decisions. In subsequent sections we discuss how the consumers' expectations regarding product lifetimes affect their buying and replacement decisions.

Buying and replacement decisions

The consumers' expectations regarding product lifetimes play a vital role throughout the consumption process. In the acquisition phase, consumers are confronted with the decision on whether to buy a new or used product. Consider

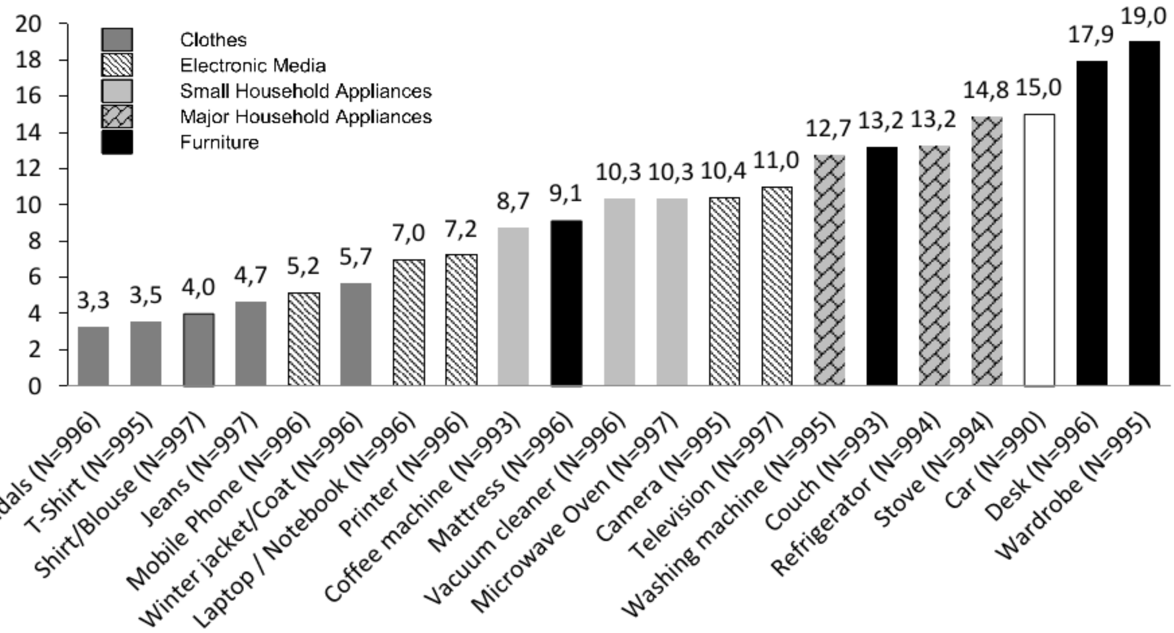

Figure 2. How long do you expect the following products to last or flawlessly function under normal intensity of use (in years and months)?

the following example: Person A generally expects a car to last 15 years.

Accordingly, she would expect a second-hand, 5-year-old car to run another 10 years. Person B, in contrast, assumes a new car to last 10 years and a 5-year-old car another 5 years only. In this case, buying a second-hand car is clearly more attractive to Person A: Whereas Person B would expect the new car to run twice as long as a second-hand car, the ratio would be only 1.5 for Person A. Hence, low expectations regarding product lifetimes make second-hand products less attractive to consumers.

Besides the decision on whether to buy new or used products, consumers also have to make a decision regarding product quality and costs. An interesting starting point is Cooper's observation that “many consumers who want longer lasting appliances do not generally purchase premium quality models” (2004: 442). He argued that consumers may have difficulties at judging the durability of products because prices are not reliable indicators for quality. However, the consumers' expectations regarding product lifetimes are important as well. Some interviewees questioned that higher quality comes with higher prices and that differences between premium and no-name products are still as pronounced as they used to be. These consumers do not expect products from premium brands to last longer and see little reason for paying higher prices for premium products. Other interviewees would expect a positive relationship between price and quality, but are anxious that a high-priced product could break down early and hesitate to invest a lot of money for premium products. In both cases, low confidence in the durability of products eventually leads to shorter use-times.

Consumers are confronted with a similar problem in the case of a mobile phone contract renewal. In Austria, consumers are typically given the choice between taking a new phone and a discount on phone calls and other services. An interviewee explained that he prefers a new phone in these situations because he is sceptical that a mobile phone would last for another two years (typical contract period).

Object	Ratios
Mattress	1,73
Stove	1,75
Winter Jacket / Coat	1,86
Fridge	1,92
Jeans	2,01
T-Shirt	2,02
Shirt / Blouse	2,03
Couch	2,05
Washing Machine	2,11
Sandals	2,14
Laptop	2,19
TV	2,20
Mobile Phone	2,50
Camera	2,51
Wardrobe	2,55
Printer	2,69
Vacuum Cleaner	2,70
Coffee Machine	2,81
Desk	2,82
Car	3,03
Microwave	3,62

Table 1. Ratios between Desired Lifetimes and Use-times.[4]

The consumer's expectations regarding product lifetimes affect also their decisions on whether to repair or replace a defective product. Consumers with low expectations regarding product lifetimes are more likely to prefer replacements to repairs because they think that the latter would not pay off. In this context, also the technicians' and salespersons' expectations regarding product lifetimes are important because they base their recommendations to customers on these expectations. For example, in one case a technician did not bring any spare parts along, because the dryer was 'already' 10 years old. In his opinion, 10 years was a reasonable lifetime of a dryer. However, although he recommended replacing the dryer, the interviewee wanted it repaired. In these situations, the expectations regarding product

[4] The ratios reported here are based on the average of each individual's ratio

lifetimes are actively negotiated between consumers and technicians/salespersons.

Finally, low expectations may also be used as justifications for early replacements. Once a product has met one's expectations, it is "mentally written off", as van Nes (2010: 116) has pointed out. The following example may illustrate this point: At the time when the dishwasher stopped working after 18 years of usage, the interviewee did not even consider repairing the dishwasher because she felt that after 18 years one can allow oneself to buy a new dishwasher. The interviewee added that if the dishwasher would have been only eight years old, she would have repaired it.

In this section we have shown various ways how the consumers' expectations regarding product lifetimes influence their buying and replacement decisions. Eventually, low expectations always lead to shorter use-times and earlier replacements. In light of the critical role of expectations, it is essential to understand how these are formed.

The formation of expectations

How long a consumer expects a specific product to last depends on a number of factors, including prices, brand, online reviews and the length of guarantee (see Cox et al., 2013; Knight et al., 2013). In this section, however, we are primarily concerned with the question why general expectations have reached such a low level. The analysis of our interviews suggests that mainly two factors are at play: past experiences and the widespread belief that built-in obsolescence is ubiquitous (see also Brook Lyndhurst, 2011).

Without being prompted, 18 out of 25 interviewees stated that in their opinion manufacturers design their products with built-in obsolescence and that this is common practice across all industries. While some concluded this on the basis of their own experiences, others referred to the logic of competitive markets. In their opinion, designing products with short lifetimes is a necessary sales strategy in a competitive environment. Some interviewees thus blamed the capitalist system rather than individual manufacturers. This widespread scepticism may be the reason why the link between brand and longevity is often questioned.

With regard to the people's past experiences, two observations are worth noting: First, negative experiences weigh much more than positive experiences. While all interviewees could easily name some products which could not meet their expectations, many were surprised to find out during the interview how old some of their possessions are (interestingly, some started knocking on wood – a sign to express one's luck in a situation considered to be *out of one's control*). Moreover, while we found many cases where our interviewees lowered their expectations due to negative experiences, none of them appears to have raised her expectations over time. The second important observation is that negative experiences with one product tend to affect the expectations of *other* products as well. One negative experience with one product can thus lead to low expectations of product lifetimes in general. A possible explanation for this is that consumers interpret negative experiences as confirmations of their conviction that manufacturers accelerate the obsolescence of their products. Since built-in obsolescence is considered common practice across all industries, one negative experience can lower one's expectations in general.

Conclusions

In the previous sections, we have outlined how expected lifetimes affect buying and replacement decisions and provided some insights into how these expectations are formed. A better understanding of these processes is key for designing strategies towards slower replacement rates. Moreover, we have presented the average use-times and desired lifetimes of 21 products. This paper was also written with the intention to bring some conceptual clarity into the debate. First, differentiating between use-times and lifetimes would make it clearer whether the products' or the consumers' perspective is taken. Second, distinguishing the consumers' expectations from what they desire, is key in order to understand how desires differ from use-times and how expectations influence both buying and replacement decisions.

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Appendix: sample characteristics

Category	*Survey N=1,009*	*Interviews N=25*
Gender		
Men	508 (50.3%)	14 (56%)
Women	501 (49.7%)	11 (44%)
Age		
18-29	241 (23.9%)	6 (24%)
30-39	205 (20.3%)	6 (24%)
40-49	249 (24.7%)	6 (24%)
50-59	206 (20.4%)	4 (16%)
60-65	105 (10.4%)	3 (12%)
Educational level		
Primary school	242 (24.0%)	/
Vocational training	479 (47.5%)	/
High school	186 (18.4%)	/
University	102 (10.1%)	/
Monthly net income (€)		
No income	51 (5.1%)	/
<1,000	161 (16.0%)	/
1,001-2,000	370 (36.7%)	/
2,001-3,000	172 (17.0%)	/
>3,000	45 (4.5%)	/
Not specified	210 (20.8%)	/
Household composition		
Single	168 (16.7%)	3 (12%)
Multiple adults	440 (43.6%)	9 (36%)
Single with children	35 (3.5%)	1 (4%)
Multiple adults with children	363 (36.0%)	12 (48%)
Region		
Burgenland	34 (3.4%)	2 (8%)
Carynthia	66 (6.5%)	0
Lower Austria	195 (19.3%)	9 (36%)
Upper Austria	171 (16.9%)	0
Salzburg Province	63 (6.2%)	0
Styria	145 (14.4%)	0
Tirol	86 (8.5%)	0
Vorarlberg	42 (4.2%)	0
Vienna	207 (20.5%)	14 (56%)

Single product, multi-lifetime components: challenges for product-service system development

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Keywords: Product-Service System; circular economy; resource efficiency; product lifetime extension; sustainable design.

Abstract: The rapid turnover in consumer electronics, fuelled by increased global consumption, has resulted in negative environmental and social consequences. Consumer electronics are typically disposed of into UK landfills; exported to developing countries; incinerated; retained in households in a redundant state; or otherwise *'lost'* with very few being recycled. As a result, the high value metals they contain are not effectively recovered and new raw materials must be extracted to produce more goods.

To assist in a transition from the current throw-away society towards a circular economy, the Closed Loop Emotionally Valuable E-waste Recovery (CLEVER) project is developing a novel Product-Service System (PSS). In the proposed PSS, component parts with *'low-emotional value'*, but requiring regular technical upgrade (such as circuit boards, chips and other electronic components) will be owned by manufacturers and leased to customers, and potentially '*high-emotional value'* components (such as the outer casing) will be owned and valued by the customer so that they become products that are kept for longer periods of time. This research conceptualizes a consumer electronic device as comprising a *'skin'* - the outer casing, or the part that the user interacts with directly; a *'skeleton'* - the critical support components inside the device; and *'organs'* - the high-tech electronics that deliver the product's core functionality. Each of these has different longevity requirements and value-chain lifetimes, engendering different levels of stakeholder interaction.

This paper contributes to academic debate by exploring the feasibility of creating a PSS which addresses conflicting issues for different components within the same device with different optimal lifetimes and end-of-life fates.

Introduction

Continuous replacement of consumer electronics and disposal into UK landfills, or to developing countries, results in negative environmental and social consequences (Widmer, Oswald-Krapf, Sinha-Khetriwal, Schnellmann, & Böni, 2005). Nearly six million small household appliances are discarded each year (Cooper & Mayers, 2000) with only 5% of them being recycled (Axion Recycling Ltd., 2006). Production of these appliances requires the consumption of approximately 125 TJ of energy per annum and over 90% of discarded products are land filled, incinerated, or otherwise '*lost*' (Darby & Obara, 2005). Europe consumes 25-30% of all the metals produced globally, but is only responsible for 3% of global metal production. As a result, Europe and the UK are becoming increasingly dependent on imports of raw materials, creating concerns about '*critical resource security*' (e.g. House of Commons Science and Technology Committee, 2011). On the demand-side, over 50% of householders are dissatisfied with the lifetime of small household appliances and think that they should last longer than at present (Mayers, 2001). Yet, while strategies to extend product lifespans are myriad, they are widely under-utilized within the consumer electronics market, which relies on obsolescence to drive continued sales (Cooper, 2004). Methods employed to reduce resource use of individuals in the Global North are typically based on voluntaristic and/or information-driven campaigns, thus failing to achieve significant behaviour change.

However, although designing products with increased physical durability may seem the answer, this does not necessarily lead to longer life spans if the *'value'* (both technological and emotional) of the product has deteriorated over time.

A Product-Service System (PSS) is a function oriented business model incorporating both service and ownership, offering a viable method for reducing material consumption:

> *"shifting the business focus from designing (and selling) physical products only, to designing (and selling) a system of products and services which are jointly capable of fulfilling specific client demands"* (Manzini & Vezzoli, 2003, p. 851).

Whilst the PSS literature highlights the importance of the citizen, current approaches to the circular economy are typically industry and design-led, focusing on developing technological solutions. Therefore, any proposed PSS would need to acknowledge citizens' needs and preferences to ensure acceptance and to overcome existing barriers to the adoption of PSS's.

Closed loop emotionally valuable e-waste recovery

Consumer electronic devices tend to be discarded rapidly and are not effectively recovered, as is the case with mobile phones we use as a case study throughout this paper. Thus *'leakage'* of significant quantities of metals from the manufacturing chain occurs and e-waste accrues (UNEP, 2011). The challenge is to encourage owners to return devices and then to recover valuable metals, so assisting the UK move towards a circular economy (European Commission, 2011).

Product-Service System – creating value

CLEVER combines a PSS model with design for emotional durability, which is design that creates an emotional attachment between the product and user to increase longevity and postpone product replacement (Chapman, 2010). As such, the project is developing a system in which components with *'low-emotional value'* that require regular upgrade (the electronic components), will be owned by manufacturers and leased to customers.

Returning these components for regular upgrades will satisfy consumer demand for the

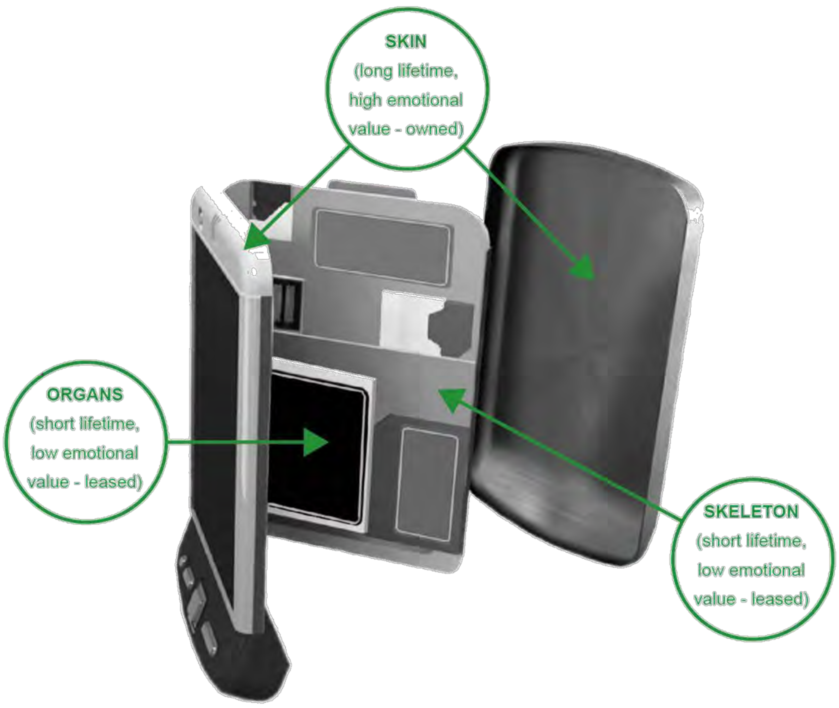

Figure 1. The 'skin', the 'skeleton', and the 'organs'.

latest hardware, whilst enabling manufacturers to retain the components that have been designed for efficient metal recovery. Potentially, *'high-emotional value'* components (such as the outer casing) will be owned and valued by the customer so that the product itself is kept for a longer period of time. Within CLEVER we conceptualise the outer casing, or the part that the user interacts with directly, as the *'skin'*. The critical support components inside the device are the *'skeleton'*, and the high-tech electronics that deliver the function as *'organs'*, as seen in Figure 1. In doing so, we propose a novel closed-loop system in which a single product can contain multiple components with varying lifetimes and value propositions.

In order to convert this novel idea into a feasible solution, CLEVER is taking a user centred design approach (Rogers, Sharp, & Preece, 2007). A *'top down'* business origami workshop involving CLEVER investigators and researchers (Hanington & Martin, 2012) has been carried out to provide a designer-centric perspective. This will be combined with the outputs from a *'bottom up'* co-design workshop with users to provide a citizen-centric perspective, as illustrated in Figure 2. From this a tangible PSS will be proposed that could potentially extend product life through the creation of emotional value, and that will differentiate ownership and service. Both the products and the service components of the proposed PSS will be prototyped and evaluated through focus group interviews (Bruseberg & McDonagh-Philp, 2002; Buchenau & Suri, 2000) before finally being evaluated in a *'real world'* context (such as in a *'pop up'* store concept format), to determine whether such a system could feasibly extend product lifetime (Maguire, 2001; McClelland & Suri, 2005). To achieve this, CLEVER will work closely with stakeholders throughout the electronic device supply chain from materials manufacturers, through electronics manufacturers and retailers, to the end user: individuals who purchase, use and (currently) frequently discard their devices, or relegate these to hibernation, rather than committing them to the recycling loop.

The first stage of the PSS design process, the internal top down workshop, has been completed and the output is presented below in Figure 3. To summarise, its key features are as follows.

- The user purchases the service contract and associated phone from a distribution platform. Several platforms were discussed during the workshop, including, but not limited to: e-commerce and online shopping; traditional bricks-and-mortar

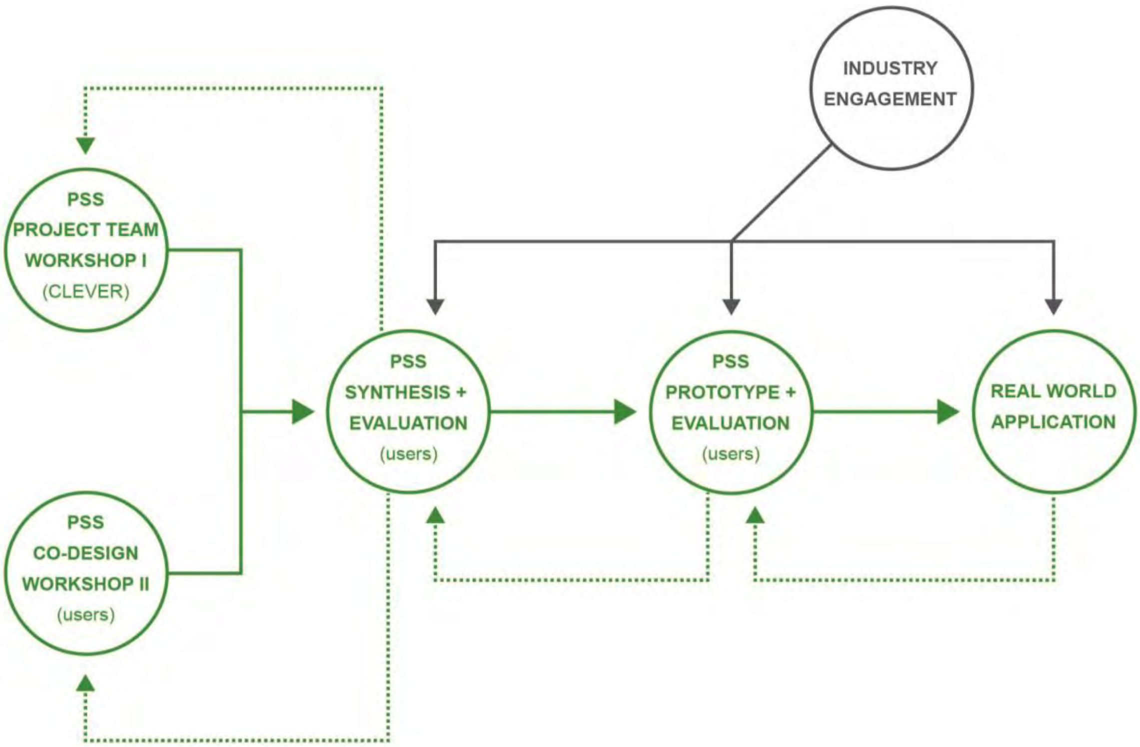

Figure 2. The PSS design process.

retail and dedicated upgrade centres; local franchises (based within, for example, a local coffee shop); independent community upgrade shops; and vending machines.

- When the user requires or desires an internal upgrade (which could be due to one factor, or a combination of reasons for obsolescence; absolute, functional, technological, societal etc. (Cooper, 2004; Packard, 1967; van Nes & Cramer, 2006)), the user returns the phone to the distribution platform and the phone is serviced (with internal hardware and software upgrades and exterior treatments as requested). The phone is returned to the user with the new internal components; the user retains the valued external skin of the phone. The reclaimed components from the individual platforms are consolidated for sorting.

- After consolidation, organ and skeleton components and sub-assemblies are either recovered for reassembly and reuse, or sent for material recovery and metal refining. Mixed metal recycling streams can input into the metal refining process here, maximising the use of external resources to negate any process losses.

- Raw materials from the materials recovery and metal refining processes are remanufactured into new organ and skeleton components. In the short term it is likely that manufacturing would occur in established world-wide manufacturing hubs for consumer electronic devices.

- Recovered and new components and sub-assemblies are assembled (as hardware upgrades, or as new phone assemblies with new skins) and circulated to the distribution platforms in order for the circular process to be repeated.

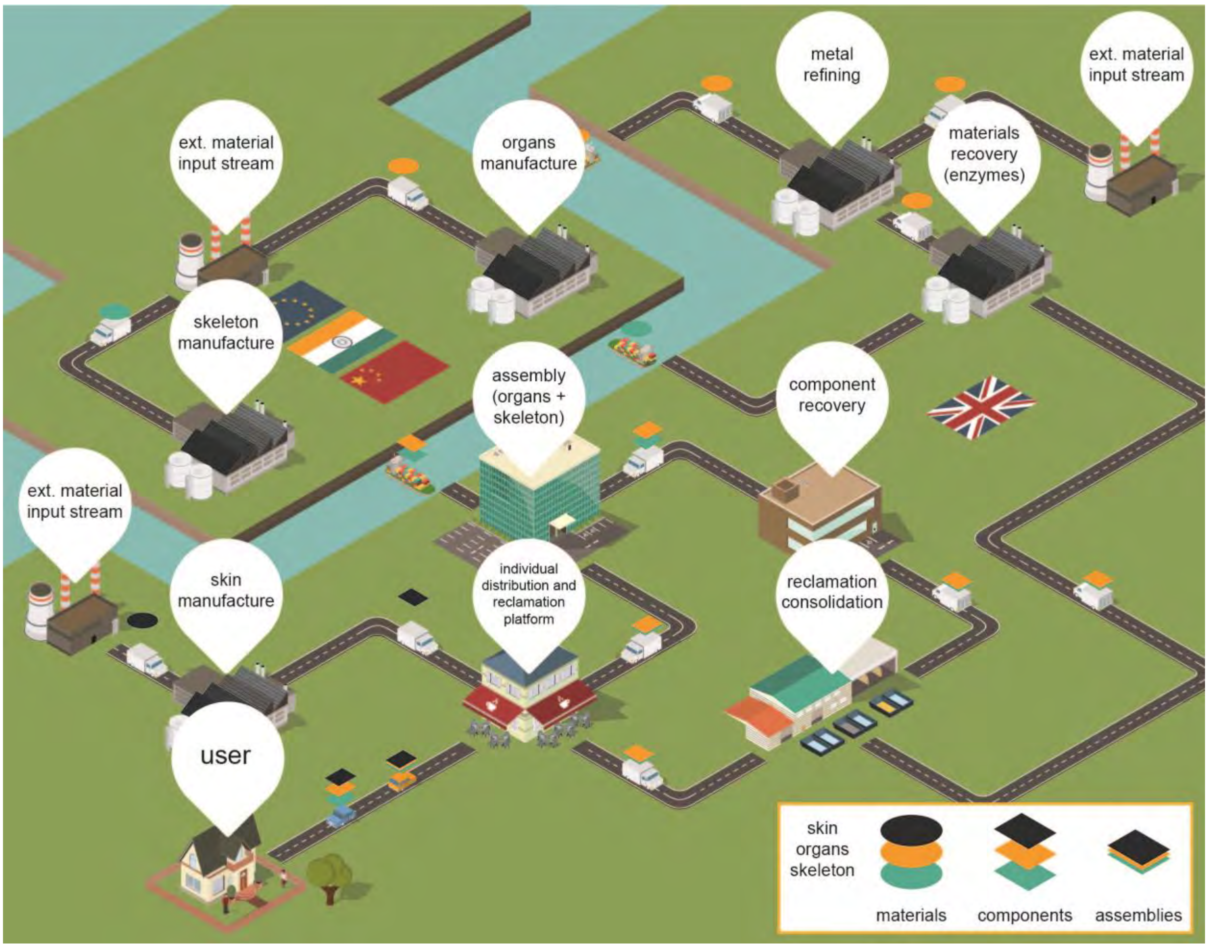

Figure 3. Output of the '*top down*' workshop.

This model is simplified in that it assumes that recovered metals must be used in the same application, i.e. phones, but, in fact, recovery of valuable, but dispersed or dissolved metals is a developing business in itself and is likely to remain so as there are benefits to combining recovery feed streams.

In order to encourage greater emotional attachment to the skin, new materials which *'age gracefully'* are being developed and consumer responses to these materials explored. To recover component parts (organs) quickly and efficiently for metals recovery, new skeleton materials amenable to degradation by enzymes, and thus release of '*organs*', are being developed. These aspects of the CLEVER project, which support the PSS implementation, are discussed in the following section.

Multi-lifetime components

Emotionally durable design utilizes the strong relationships that can exist between people and their possessions to create longer lasting products, thus postponing product replacement (Chapman, 2010). *'Heirloom materials'*, which increase in emotional and aesthetic value with age, have been proposed conceptually by product designers, but have not yet been engineered, and limited work has been carried out on correlating consumer response to physical characteristics of materials (Karana & Hekkert, 2010). The desire to retain the external '*skin*' of an electronic device creates an incentive to return the product for upgrade, rather than purchasing a new device, allowing the manufacturer to recover the skeleton and organs, vital within the context of our PSS.

In response to this challenge, CLEVER is developing and prototyping its own materials with heirloom characteristics, manifest with visual complexity and variability of surface texture, and appropriate response to wear and ageing. Design requirements for heirloom materials for consumer electronics are being developed through an investigative process of understanding the physical properties of natural materials, that, in certain contexts, increase in emotional value with age (e.g. wood or leather). These requirements are informed by the testing of materials towards an understanding of emotional responses elicited by such materials, combined with conventional material requirements, such as strength, stiffness, weight and cost. New materials based on these design requirements will be prototyped and assessed for creation and sustenance of emotional attachment.

In addition to the development of new materials, it is recognised that the decoupling of the longevity of skins and internal components provides opportunities for the use of materials with appropriate lifetimes, which in turn helps facilitate end of life recycling and recovery of valuable elements contained in the organs. Chiodo and Jones' work on active disassembly using smart materials (2012) aimed to rapidly separate the skin and skeleton, and here we complement this approach by developing new materials that ease the separation of skeleton and organs.

The most important characteristic of these materials is that they will be stable and robust while in use, but can be triggered to decompose when the device is to be taken apart for recycling. Here we must differentiate between 'triggered disassembly' referred to above, which uses shape memory materials to allow rapid separation of skin elements from skeleton/organ assemblies and 'triggered decomposition', which breaks down the skeleton releasing organs. This will facilitate the recovery of the valuable metal containing electronic organs, so that these can be efficiently recycled and retained in the closed loop of electronics manufacture. Towards this objective the CLEVER project team are developing biopolymer composite materials, based on cellulose in the first instance, for skeleton elements such as printed circuit boards and flexible printed circuits, which are robust in use, but amenable to intentional degradation at the end of life, either enzymatically, or by disintegration or dissolution in solvents such as ionic liquids. This degradation will release metallic components, providing opportunities for recycling. Metals for recovery will be prioritized by value, scarcity and ease of integration of the technology into recycling processes. Electronic components, metal solders and contacts will be recovered by physical screening or flotation separation from the enzyme broth, or by a combination of these techniques and electro-winning from ionic liquid solution, post skeleton decomposition.

Feasibility and effectiveness

In the development of any new product or service, it is vital to robustly demonstrate that the new system delivers real benefits across a broad set of indicators including environmental, social, cultural and economic impact and sustainability. Here, the CLEVER project employs an environmental life cycle approach and facets of Social Life Cycle Assessment (SLCA) to underpin on-going research and to ensure that the proposed PSS, and multi-lifetime components contained within, are both feasible and effective.

The life cycle approach, essentially a streamlined LCA, assesses the potential impacts most relevant to resource efficiency throughout a product's life from raw material acquisition through production, use and disposal. CLEVER employs this approach here as a technique for assessing the environmental aspects and potential impacts associated with new designs, materials and processes for the skin, skeleton and organs of electronic goods. Of interest are products to which consumers are likely to develop an emotional attachment; the production of the functional components of devices and the practical recycling of these; materials processing and recycling; and the mining and production of metals used in component manufacture. Following a benchmarking of existing product and service components, an adaptable model of the new product-service system will be developed and the results iteratively fed back to inform the PSS, materials and recovery process design. Thus, the approach serves to inform all aspects of the CLEVER project, guiding the development of, and providing input to, the stage-gate approach that will be used to establish whether or not new materials, product-service systems and materials recovery processes are an improvement on current practice.

In addition to understanding and evaluating the environmental aspect of the proposed PSS, the CLEVER project is also exploring the potential impacts of the proposed PSS upon society. Of late, a variety of methods and tools under the auspices of Social Life Cycle Assessment (SLCA) have been developed. While these tools are useful primarily on existing products and services, facets of SCLA are key to CLEVER, such as the observation that *"the social (and socio-economic) impacts to be covered in an assessment and the way this should be done should be case and context specific"* (UNEP, 2009, p. 32). In light of this – and due to the limits of applying SLCA to a theoretical PSS - CLEVER will explore the reactions of a range of key actors to the PSS through, for example, qualitative interviews with key stakeholders and focus group with potential users, to gauge responses to the new PSS.

Conclusions

A common criticism aimed squarely at PSS literature is that the bulk of it is hypothetical. That is to say, despite the steady rise in the sustainable product-service systems corpus, there is a distinct lack of tangible and physical case studies that go beyond theoretical explorations. As articulated within this paper, CLEVER seeks to, and is in the process of, going beyond these acknowledged limitations towards an implemented *'real world'* solution. This project programme therefore is designed specifically to identify the *tangible* impacts of the PSS, including social impacts (behaviour change), environmental impacts (closing the recycling loop), manufacturing impacts (novel materials, which enable the aforementioned impacts), and economic impacts (the business case for the novel PSS and the retention of valuable metals in the manufacturing cycle).

We propose that multi-lifetime components within a single product can increase product longevity and facilitate the recovery of valuable metals within a system model. Within this PSS, components with *'low-emotional value'* but requiring regular upgrade (the *'skeleton'* and the *'organs'*) are owned by manufacturers and leased to the customer, and *'high-emotional value'* components (the *'skin'*) are owned by the customer. Thus, by differentiating between ownership and service we can create longer lasting products with components that have more appropriate lifetimes, commensurate with their function and value, thereby helping to move the UK away from the *'throw away'* society it has become. A work in progress, the CLEVER project is currently in the process of developing the PSS that will encompass these proposed characteristics and attributes, whilst in parallel developing the materials and technologies that will support its realisation. Through a combination of workshops, laboratory testing and prototypes informed by public and industry stakeholder engagement, we will rapidly move beyond the theoretical, which underpinned with robust and stage-gated streamlined environmental life cycle approaches, and social life cycle assessment, will enable the selection of the *'best'* solution for overall life cycle, thereby ensuring that the PSS proposed is both feasible and has long term benefits.

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The sustainable future of the Scottish textiles sector: challenges and opportunities of introducing a circular economy model

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Keywords sustainability; circular economy; textiles; closed loop technologies.

Abstract The Scottish textiles industry is worth £956 million to the Scottish economy and is the seventh biggest contributor to it. Zero Waste Scotland (ZWS) is spearheading a series of initiatives in Scotland with other organisations, including universities that will encourage the introduction and, further uptake of, resource efficient and sustainable materials and processes into textile supply chains and the economy, to contribute to a sustainable circular economy model for the sector.

In April 2014, the Scottish Government launched the Textiles Futures Forum which is providing a £450,000 Challenge Fund. The key aim is to develop research initiatives with industry and academia that push sustainability and resource efficiency to the fore. Consequently, as a result of that and an internal report submitted to ZWS in 2014, ZWS is now focussing on five key areas to achieve that key aim through circular economy models.

It is implementing an action plan which will offer support to the textile industry to explore 'closed loop' manufacturing as well as funds for fashion designers to explore concepts such as zero waste pattern design, luxury apparel from alternative textiles such as recycled polyethylene terephthalate and natural fibres such as Scottish rare breed wool. A master class skills programme, delivered by leading UK and international experts, will bring together industry, academia, and higher education professionals to engage in learning about the circular economy. These initiatives will be evaluated to inform future work plans and learning.

Introduction

Zero Waste Scotland (ZWS) was initially a programme of the Waste Resource Action Programme UK (WRAP UK). On 1 July 2014, ZWS was launched formally as an independent Scottish not-for-profit company.

ZWS' textiles portfolio is a key sector within the Circular Economy Team portfolio, which also covers Oil and Gas Decommissioning and Circular Economy Business Models. The textiles sector is the seventh most important contributor to the Scottish economy, with an annual turnover of £956 million. Exports of its products are valued at £375 million. There are over 570 companies directly employing about 9,000 people across Scotland, with 55% of these companies having fewer than 10 employees.

Global economic trends have influenced, positively, the export of luxury goods for the Scottish textiles sector. In October 2013, it reported growth levels 12 per cent above the 2020 target. It has revised its targets to achieve between £1.2 and £1.5 billion in turnover growth by 2020. These revised figures recognise the significant gains to be made in international trade and a 50 per cent increase in exports is predicted by 2017 (Scottish Government, 2014). Sixty-four per cent of textile production in Scotland is for luxury export goods (Scottish Enterprise, 2014). Chanel, for example, announced in April 2014 that it would create 100 new jobs over the next three years at its plant in Hawick, having bought out a knitwear company in 2012 and established itself in the Scottish Borders (Knitting Industry, 2014).

This increased textiles and apparel productivity could contribute to global waste and environmental impacts but it can be reduced by designing and manufacturing goods that follow circular economy guidelines, or by creating products with a low carbon impact. Scotland is already developing key products and customers in this market, such as the Harris Tweed Authority, which reported a 25% sales increase in 2013 (Harris Tweed Authority, 2013).

ZWS's key aim, then, is to ensure this innovative and re-energised sector builds in circular economic approaches that not only minimise global impacts, and without economic detriment to individual businesses, but that sees the circular economy as a key tenet of any business model. The textiles industry must work more closely with academia and recognise mutual advantages. The goal is to make the textiles industry in Scotland more resource efficient, sustainable and competitive in a global market, while underpinned by mutual learning across industry and academia.

In a broader context, this work is part of ZWS' support of the Scottish Government's Zero Waste Plan (Scottish Government, 2010) which has set ambitious targets to achieve 70% recycling and a maximum 5% to landfill by 2025 for all Scotland's waste. 'Safeguarding Scotland's Resources', launched on 9 June 2013, is the Scottish Government's programme to reduce waste and create a more productive and circular economy (Scottish Government, 2013) with one clear benefit: 'There is a potential saving of £2.9 billion through straightforward resource efficiency that this programme will help tap.' The Scottish Government has sealed its commitment by being the first government to join the Ellen MacArthur Foundation CE 100 (Scottish Government, 2013).

The circular economy is, of course, more than just another name for 'reuse'. As the Ellen MacArthur Foundation says:

> *'The circular economy is a generic term for an economy that is regenerative by design. Materials flows are of two types, biological materials, designed to re-enter the biosphere, and technical materials, designed to circulate with minimal loss of quality, in turn entraining the shift towards an economy ultimately powered by renewable energy.'* (Ellen MacArthur Foundation, 2012)

To help shape its work plan for textiles, ZWS commissioned research which was completed and published internally in September 2014. It concluded that the Scottish textile industry is innovative in key sectors, particularly 1) technical textiles and 2) computer-aided design. However, in both cases, the overarching objective is either to increase business competitiveness or improve resource efficiency, rather than closed loop sustainability and corporate social responsibility.

Report findings

The report recommended that the Scottish textile industry should focus on strengthening what it already does well and bolster its sustainability activities by linking to provenance, traceability, durability and quality. Inspiration should come from the luxury goods sector and also, in a more modest way, from Scandinavian brands such as Filippa K, where longevity is an explicit brand strategy.

In April 2014, the Scottish Government launched the Textiles Futures Forum (TFF) which is providing a £450,000 Challenge Fund. With funding from the Scottish Funding Council, the aim is to develop research initiatives with industry and academia that push sustainability and resource efficiency to the fore.

The report submitted to ZWS, its own analysis of its work to 2014, and the TFF initiative, identified the challenges and opportunities that can make the Scottish textile industry more materially circular. Consequently, ZWS is now focussing on five key areas:

1. Industry and academia – skills training
2. Fibre-processing facility
3. Textiles and apparel
4. New business model research
5. Funding to experiment with closed loop technologies and systems.

This paper outlines ZWS' work plan for the first three key areas.

Industry and academia – skills training

The report identified the need for skills development for the textile sector that would see a greater integration between industry and academia to achieve greater circularity.

To reach this goal, ZWS will deliver master classes between April-December 2015.

Participants will learn about resource efficiency and skills for a circular economy, such as design for disassembly and fibre processing, zero waste pattern design and new dyeing and printing technologies.

The majority of the 16 places for each course will be allocated to industry, with a quarter allocated to academia and educationists who are developing curricula. Attendance is by invitation and application and candidates must evidence how they will cascade the learning within their business and to colleagues.

Each facilitator will travel to Scotland from other parts of the UK or Europe (where possible, webinars will be used). To maximise facilitators' visits and learning, a student lecture series will accommodate up to 200 students at each lecture.

Skills Development Scotland has confirmed that it is complementary to the Scottish Textiles Skills Action Plan that has been funded recently by the Scottish Funding Council while the Textile Institute has expressed an interest in accrediting the master classes.

The impact of the participants' learning experience will be evaluated by an independent consultant documenting how they have cascaded their learning or implemented new skills in their business processes.

Fibre-processing facility

Scotland does not have a fibre or bulk waste textile processing plant. In 2012, a ZWS report outlined the economic case for a mattress recycling facility. ZWS supports a fibre-processing facility in Scotland that would process the numerous lower-grade bulk textiles which currently go to landfill, including carpets, mattresses and post-industrial waste. It would also boost investment and jobs, adding value to materials which are currently worth little. For example, if 60% of mattresses can be recycled (7,200 tonnes equates to 335,000 units), the number of direct jobs created is estimated at 80, based on the ZWS business case of eight jobs per 34,200 units.

Such a facility would also enable Scotland to process products from across the UK and achieve a market share of this aspect of the textiles economy. Cotton and polyester constitute, respectively, half and one quarter of the UK clothing fibre mix and so are key priorities for fibre processing. Mixed fibres such as wool and nylon are characteristic of carpet construction and mixed fibre extrusion is still a developing area. In the case of carpets, Anglo Carpets in England employs 35 people to process 1,200 tonnes. Carpet Cycle employs 50 people for 5,500 tonnes. Mid-point is one person per 75 tonnes processed. If Scotland could achieve some of that market share and avoid its current transport costs that would support broader circular economy aims for the textile industry.

ZWS' specific priorities for the reprocessing of cotton and polyester are based on recommendations in the WRAP report, UK Textile Product Flow and Market Development Opportunities. These are to investigate the potential for Scotland to reprocess cotton and polyester as fibre, or feedstock, at cost parity to virgin material. ZWS recognises that scale could limit implementation of a reprocessing infrastructure therefore this work plan will be subject to constant review.

The immediate ZWS priorities for the fibre-processing facility are:

- To identify candidate technologies for fibre processing; and the financial support required to enable proof of design, trialling and scale-up.
- To create a route map of the actions needed to deliver a commercially-viable service.

Textiles and apparel

> *"Eighty percent of a product's environmental and economic costs (are) committed by the final design stage before production begins"* (Graedel et al, 1995, p. 257).

To address this, ZWS launched the first Circular Economy Textiles and Apparel Grant Fund in December 2014. It is open to textile and apparel designers who want to apply more circular economic and resource-efficient design practice to new products and textile construction, such as zero waste garment design, design for disassembly, sourcing and designing with alternative fibres such as recycled P.E.T. and fibre dying and processes.

The fund criteria suggest applicants should:

- Design new textile or apparel products that could be manufactured in Scotland on a commercial scale or have a significant impact on the current design of a product design process
- Redesign a current product from their business model but apply circular econ-my and/or resource efficient principles
- Research and develop new textile and/or apparel collections that aim to apply circular economy principles or resource efficiency.

Seventy-two applications were downloaded and 12 applications received. Five grants were awarded, at £7000 per recipient. This included a cash grant, mentor fees and a travel allowance to visit mentors. Each recipient proposed to push the technical boundaries of their product by working towards zero waste or design for disassembly, or with new materials such as Returnity©, 100% recycled polyester. Within the companies awarded funding, there is a heavy emphasis on natural fibres, exploring the reinvigoration of Scottish sheep breeds.

Each recipient company will have an expert mentor at the early R&D stages, including circular economy textile experts from the University of the Arts London and Leeds University, as well as international experts Refinity©. ZWS' ambition is to identify products that demonstrate where the niche is for Scotland in the circular economy, closed loop design and production. Each company is a relatively new business. Some owners have a degree of experience of taking products to market; two of the companies have experience in wider product design and environmental skills.

The fund received wide media coverage in both textiles and resource industry press across the UK. Scotland has a small but growing fashion social media community with a large following and that ensured that community was encouraged to submit applications.

ZWS received no applications from technical textile SMEs such as the growing outdoor apparel industry, for example, companies such as Keela and Endura performance cycle wear, which would have been welcome.

More broadly, demand for hand-crafted products that draw on Scotland's textile heritage and once declining Scottish skills such as hand knitting, have been invigorated by knitwear design companies such as Eribé knitwear in Galashiels in the Borders. It has 200 registered hand knitters who can earn between £100-£400 per month producing contemporary Scottish knitwear for export, mainly to China and Japan. Other Scottish hand knit companies, such as Di Gilpin, in Largoward, Fife, have been involved in product design for Nike, supporting the development of Nike Flyknit® running shoes (The Scotsman, 2015), demonstrating the trend for global brand to reference craft heritage as part of their product development strategy.

Through support from Scottish Enterprise, companies such as Eribé have doubled their turnover in five years, mainly through exporting (Scottish Government, 2014,). Their challenge is to source sustainable Scottish raw materials such as wool from Scotland (other than from Shetland) and a growing number of small sheep crofts. The textile sector must be aware, however, that a revival in craft heritage must pay heed to existing industry frameworks. For example, since 1952, a sheep farmer with more than four sheep is required, legally, to sell wool only through the British Wool Marketing Board (BWMB). The penalty, if enforced, is still a six-month jail term. In 1995, this legislation was relaxed to allow farmers to sell wool only for direct export.

International relations – Scandinavia

The report submitted to ZWS for internal use found evidence of global trends, and examples of current closed loop practice and circular economy textile models in other countries, including the UK, that could be applicable to Scotland.

The report's researchers suggested finding case studies in Europe that might provide inspiration and examples for Scottish textile businesses to follow. Scandinavia was the focus and a number of circular economy examples in textiles were identified.

The Research Council of Norway (NICE) funded a three-year project (2010-13) valued at €500,000, with a view to identifying and promoting the benefits of textiles made of Norwegian wool to local consumers. When the project ended, NICE wanted to continue its research and use the heritage and technology it had discovered to develop further consumer demand for Norwegian wool and create a label of provenance, similar to Harris Tweed, called the Nordic Swan eco label. As part of this research, they chose to visit Shetland where fleece is gathered from over 700 crofters to produce Shetland wool.

Norway also developed a product which was given an international standard approved Cradle to Cradle (Research Council of Norway, 2013). The Dutch airline, KLM, wanted to create Cradle to Cradle carpeting working with Desso. Norwegian wool was tested for chemicals, etc and was approved. On behalf of ZWS, the report's researchers brokered an introduction to the National Institute for Consumer Research (SIFO).This resulted in the potential to develop research collaborations around wool and revise the heritage of Scottish and Norwegian knitwear. In this way, each country can work towards a model of provenance, traceability, durability and quality, as per the four key values mentioned earlier that the ZWS-commissioned report recommends.

Conclusions

Measuring the impact of a circular economy approach is a task for the long term and ZWS knows, from industry examples such as TENCEL® by Lenzing (Lenzing Group, 2014), that it can take up to 30 years to develop a product that revolutionises industry.

'The production of TENCEL® is revolutionary. The production process is based on a solvent spinning process and represents the greatest accomplishment in cellulosic fibre technology. The unique closed loop production process makes TENCEL® the fibre of the future: eco-friendly and economical.' (Lenzing Group, 2014)

This paper has outlined ZWS's strategy, the reports and initiatives that are behind it, and our work plans for the Scottish textiles industry. The key focus is supporting resource-efficient, circular economy models in the sector. ZWS is supporting a sustainable textiles industry that will generate long-term growth as part of a circular economy and one that is aligned with the Scottish Government's overarching zero waste targets for 2025.

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Vernacular as the dialect of the uncommon

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Keywords: vernacular; product durability; concept; indigenous; design thinking.

Abstract: The term vernacular occupies the 'space between' - balancing anonymous design and authored products, and raises many interesting questions concerning user–object relations and product life. On the one hand it can question the position of regionalism in product design and the cultural attachment of objects to localities; on the other, applies to a wider discourse of sustainability, material efficiencies and durability.

This paper will focus on vernacular design and how location-specificity in object culture, can challenge issues of throwaway consumer culture. The vernacular object reveals that *identity* is of primary significance due to the utilization of localized materials and forms. This is often the result of evolution rather than planning, and the resultant product expression is regional and site-specific. Vernacular object-traits are unmistakable and as such are markers of defined spaces. The immediacy of materials and an emergent object style could be supposed to conjure the environment more than any other. The fundamental issues of the enviro-product relationship, material efficiency and user-centricities, are central to understanding aspects of product longevity. They are a portrayal of indigenous character, but also the indigenous experience. Are vernacular products examples of socially conscious design because they express the environment of derivation? Could they be a model for product durability and sustainability?

The paper argues that place-defining objects are an 'under history', and as such, have been neglected in a current discussion of product lifespan. It considers the key issues of the concept of the vernacular and argues that it is worthy of wider inquiry in the context of the design-thinking discourse post 2005, to explore its potential value as a contemporary model for product durability.

Introduction

This discussion focuses on a discourse about the vernacular and its application to contemporary issues of sustainability and product lifespan. It concerns debates about the vernacular as a concept, but specifically vernacular as a manifestation in the design of objects. There is a legacy of scholarship concerning the vernacular that is stronger in some disciplines than others, for example literature and architecture. In design history it is a neglected field of study and according to Glassie (1999, p. 8) the study of the vernacular requires "transdisciplinary attention" which, in the study of products, is between "history and anthropology". He suggests the historian is a "cultural geographer" (199, p. 27) as the study of the vernacular is about distinct characteristics of similar social patterns. So the vernacular object could be considered to occupy the 'space between', both as a field of study and as a type of product not necessarily driven by professional engagement and commerce. As an 'outsider' or 'under history' it may be useful to examine the theoretical issues concerning the vernacular object more thoroughly, with the intention to re-position it in a contemporary debate of product design, the environment and durability.

Defining the vernacular

Vernacular is a form that evidences the influence of the environment and the place of origin. In this sense it is not just an object but also 'an effect'. (Jameson, 1992) Kouwenhoven (1962, p.259) comments "no detailed record is kept until long after the patterns have crystallized and have become habitual". Therefore a change in conditions enables new vernacular form to emerge, but they also require repetitiveness for the traits to be acknowledged as commonplace. He explains that it is difficult to trace the emergence of vernacular form because they are not recorded, and only when they are distinct, do they tend to reach a wider public attention or conscience. He uses the example of the 19th century European emigrant's axe which they brought with them to the USA. It was only when these tools were beyond repair that new ones were forged, subsequently some of these rural implements were 'improved upon'. Written documents stated that there were 'American' features applied to objects such as the hoe and the axe, which were not evident in their European counterparts. In essence, the original tools became distinct to and of their new environment as a result of necessity and geographical circumstances. This example is typical of how vernacular characteristics are established.

It implies that the vernacular emerges as a result of a process, which is interesting, as vernacular form is often labelled as 'traditional'. The term 'tradition' suggests a prescribed set of characteristics, yet vernacular form is an evolving form, which at some point becomes settled, or stable. So, to reach public recognition, repetitive vernacular characteristics within a small geographical area, create a recognizable set of characteristics specific to the locale. As a consequence, it is at this point in its process of evolution that the vernacular is recognized as traditional. This process implies a threshold, or a point at which the vernacular is created; it oscillates between an isolated, localized form and recognizable prevalence, that is expressive of the region.

Architectural history includes a broad discourse on the vernacular, and Brunskill (1971, p. 23) determines where vernacular begins by dividing architecture by type and developing a theory of the "vernacular zone". He divides domestic building by type, "The Great House, the large house, the small house and the cottage" (1971, p. 22). He considers the small house as the most prevalent form, and therefore where 'vernacular' begins:

"For the human backbone of the nation there were the small houses. The ordinary yeoman, the tenant farmer, the miller, the smith, the minor official, the unfavoured parson, the shopkeeper, the schoolteacher, were people of significance in the village, but of little standing in national or provincial society. They lived in small houses, and their dwellings make up the main body of material, which is recognized as domestic vernacular architecture." (Brunskill, 1971, p. 22)

In Brunskill's definition, vernacular is a term given to the 'zone' of the ubiquitous, and in the realm of the 'ordinary'.

Immediacy of materials, identity and place

If ordinary embraces the everyday, then materials prevalent to an area must be part of the vernacular process. Brunskill (1971, p. 26) comments that local materials (not imported) create vernacular form, so the immediacy of materials contributes to a distinct form. Risatti (2007, p. 60) emphasizes that material is what contributes to the tangible physicality of the object and therefore, "the point of origin being the point of inspiration." According to Lupton and Miller (2009, p. 23), it is the "truth to materials", which is fundamental to establishing the vernacular which requires a "transparency about where goods come from and how they are made". That is, place and local materials are integral and their combination conjures the local environment more than any other. Koewenhoven (1962, p. 259) defines the vernacular as creating, "indigenous beauty out of crude materials". He suggests that a plain, uncluttered form is what segregates the vernacular from "cultivated forms" which he describes as an expression of "unreasonable fussiness." Kowenhoven calls the vernacular "unpretentious" and which suggests that it is not swayed by national stylistic influences. Therefore a recognizable vernacular form has to be significantly variant to the dominant aesthetic and demonstrate its distinction through material and form. This hypothesis is supported by Brunskill (1971, p. 26) who comments that the vernacular has to:

> *"have been guided by a series of conventions built up in his locality, paying little attention to what may be fashionable on an international scale."*

Therefore the vernacular object is the result of a design process WITH constraints. The impact of the constraints – the place, people and materials – are key contributors in the creation of indigenous form.

The inequity or distinct character of an indigenous object to those more dominant (national) is the result of local production. The proximity of the vernacular form to its environs in its use of materials, its production and its style, are therefore considered to be expressions of place.

Therefore the vernacular reveals *identity* as a primary significance. Vernacular forms prove the "significance of quite localized geographical factors" according to Brunskill (1971, p. 18). So we can position vernacular expression in a context of the cultural attachment of objects to localities. Koewenhowen (1962) comments that the vernacular offers "a direct, uninhibited response" to the environment and the evolving forms "firmly rooted in the contemporary experience". So the vernacular both emerges and responds **from and to**, its environment. The key concerns are available materials, and a continuation of existing forms as a pattern or model within a culture of the everyday. The repetitive nature of these fundamental characteristics removes it from dominant design aesthetics, creating its 'outsider' credentials. So the enviro-product relationship is central to understanding the vernacular, it is the result of "social formation". (Risatti, 2007, p.61) This phrase is useful because it relates the process of making to the place of origin, as part of an embedded or immersive practice. The vernacular provides us with a site-specific, place-defining object; the paradox is that it is both ordinary and distinct. According to Clifford and King (2006), "the unusual, the special …may be important factors in giving a place a sense of itself."

Literature suggests that *sense of place* is bound more rigidly to a rural context not urban, as rural communities establish a different way of being (Thomas et al., 2011). Brunskill (1971, p. 15) suggests that the vernacular is prevalent in rural culture because it "remained intact, ….. traditions accumulated over several centuries". He also suggests that the vernacular is no longer evolving because we are generationally disassociated from agrarian life. If this is accurate, then it provides a reason why the vernacular has been neglected in a contemporary debate – we see the vernacular as a style of the rural past (tradition), and not having contemporary currency to contemporary urban society.

The vernacular as an interventionist model

If the vernacular is an example of social formation and demonstrates the

> *"conceptualization of the relationship between necessity; purpose; function; form; material and technique"* (Risatti 2007, p. 63),

is it applicable to contemporary culture? In an era of design-thinking we can explore if the vernacular model is applicable to a wider discourse of environmental concerns and product durability.

In 2005, Thakara stated we are in a period of "design mindfulness", (p. 226) suggesting that we are in an era of rethinking design practice. Brunskill (1971, p. 26) comments that the vernacular has to "have been guided by a series of conventions built up in his locality, paying little attention to what may be fashionable on an international scale" beyond its commercial boundaries. The consequence of which is that the 'concerned' designer can reconfigure the design paradigm to address social rather than economic issues. Contemporary discourse in design uses the phrase *transformation design*, which describes a process that "asks designers to shape behaviour – of people, of systems, of organizations – as well as form" (Chick & Micklethwaite, 2011, p. 37). The authors explain that it involves participatory "principles and methods" (2011, p. 37) and that a sustainable solution would create a "shared story" (2011, p. 97). These key concepts are easily appropriated to the vernacular model as it exemplifies the integration of people, environment and materials; thus shaping behaviour and shaped BY behaviour. In this sense it is an example of participatory design as defined by Chick and Micklethwaite (2011). The vernacular model embodies three of the key elements that the authors (2011, p. 106) recommend, "design modification and design pragmatism" and using "existing design processes … as starting `point". The vernacular model can be mapped onto this discourse and in doing so is a form of intervention or activism as:

> *"design activism is design that explicitly supports a particular cause, which is outside the core concerns of mainstream,*

commercially driven professional design practice" (Chick and Micklethwaite, 2011, p. 59).

This relates to the 'outsider' ideology of the vernacular whose core concerns (discussed earlier) are the ordinary, significant only to everyday, and part of the non-professional design process. According to Chick and Micklethwaite (2011, p. 62), design activism seeks to be "inclusive" and is "seeking out alternative visions for society" for sustainable design futures. They advocate an interlocking system where economy, society and environment are integral, leading to a state of 'equitable, bearable and viable' product design. Thus creating an extended lifespan, which, they argue, is part of sustainable future. Walker (2006, p. 17) suggests that the phrase sustainability should be used to articulate shared principles and values to reinforce the notion of a 'shared story'. The notion of the collective rather than the individual underlies these ideas and numerous authors (such as Chick and Micklethwaite, Walker, Fry) are advocating similar ideologies for our design future. According to Chick and Micklethwaite (2011, p. 97) it relies on a set of values, which have been "increasingly forgotten in the rapid growth of industrialized modern society". This resonates with Brunskill's thesis of the early 1970s, which suggests that the reason the vernacular was extinct was due to the generational dislocation from agrarianism. The design-thinking debates around sustainability (post 2005) focus on a shift in attitude of which the *concerned* designer is key. Fry (2011, p. 252) advocates "radical change" and foretells a future in which

"status related conspicuous consumption, commodity desires and aspirational consumerism are all ill-fated and will die".

His 'living otherwise' manifesto includes:

"a new kind of active life that is highly social and very much orientated toward cultural production and a material culture that is smaller but enriched" (2011, p. 252).

It is within this paradigm that the vernacular has a role to play; 'smaller' in terms of scale, 'enriched' in terms how the vernacular embeds itself in cultural significance because it emerges from, rather than, is imposed upon. The vernacular concept is useful because it can intervene in the design process at inception. Lewis and Gertsakis (2001) discuss the need to have a DfE approach (design for environment):

"the fundamental objective is to design products with the environment in mind and to assume some responsibility for the products environmental consequences as they relate to specific decisions and actions during the design process" (2001, p. 16).

They mention, "products are often thrown away because they have lost their social and cultural attractiveness", and suggest the key is a change in consumer attitude from one that values "ownership" to one which values "utilization" (2001, p. 189). They recommend that design should develop new "solution strategies" (2001, p. 191) which are user-centred. On reflection, the vernacular model is pertinent because it counteracts the social /cultural trend associated with a throwaway culture. It is socially conscious design emerging from a site-specific need, simultaneously expressing the environment of derivation. In contemporary discourse, Slow Design thinking embraces an approach that facilitates the vernacular model:

"Slow design reveals spaces and experiences in everyday life; considers the real and potential "expressions" of artifacts and environments; rely on sharing, co-operation so that designs may continue to evolve into the future; encourages people to become active participants in the design process; recognizes that richer experiences can emerge from artifacts and environments over time." (Strauss & Fuad-Luke, 2008)

Attention to detail is inherent in slow design principles as it emphasizes that awareness of ordinary traits (particular to place), requires patience. As Clifford and King (2006) comment, "differentiating the ordinary demands close observation." The key issues in the quotation are 'everyday', 'emerge' and, evolve', and these are the exact terms used earlier in this discussion in defining the vernacular. Therefore we could resurrect the concept of the vernacular from "an extinct form (one which was a fixed entity at one time) but is no longer in used for contemporary form" (Heath, 2009, p. 19), to an active agent in contemporary transformatory design practice.

Conclusions

Vernacular is an environmentally sensitive concept as it arises from socio-eco characteristics on a small scale. Vernacular is not about re- creating, mimicking or replicating existing product forms; the concept offers an exploratory investigation of materials, expertise, form and socio/cultural economic conditions within a designated locale. Therefore facilitating NEW forms. The historical legacy of vernacular has been predominantly rural but it could be applied to an urban context. This requires a shift in thinking in order to create an intertwined design process ensuring user–object relations and sustained product life. Crucially, the vernacular object portrays indigenous character, but also enables indigenous experience; and as such creates a sense of attachment. This is one method of ensuring product durability as throwaway is disenfranchised.

To conclude, the vernacular is a dialect, a form of localized narrative. It is socially constructed through distinction of form but is not fixed; more importantly, it is a concept with flexible outcomes. The emergent form takes time to form but once stable, is visually expressive of place thus providing a model of continuity and community. It allows new forms to arise (albeit slowly) but at the same time, is localized and place-bound. In essence, vernacular is a response; creating commonalities that are uncommon. Fry (2011, p.45) comments we have ‘commonality in difference” and this is exactly the role of vernacular. It celebrates difference simultaneously with identity and sense of place, and therefore offers a sustained relevancy. Its transforming properties could be resurrected and re-purposed to create product durability. Crucially the concept of the vernacular converts ‘matters of fact to matters of concern’ (Latour in Brown, 2004, p.225) which is the underlying issue of many of the contemporary discourses on product sustainability’s and design practice.

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Lifetime of electronic devices in Vietnam and comparison with Japan

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Keywords: Vietnam; lifetime; electronic devices; questionnaire survey.

Abstract: For sustainable treatment of e-waste in Vietnam, the lifetimes and possession ratios of various electronic devices (colour television, refrigerator, washing machine, air conditioner and personal computer) have been investigated through interview investigation. It was found that almost all of the electronic devices were made in Japan or Korea in 2007. Especially, the ratio of Korea was relatively high in the case of TV, while Japan was high in cases of washing machine and refrigerator. The number of possessions per household is increased with the increase in household income for all devices investigated. The average lifetimes assuming Weibull distribution were estimated 7.3, 6.2 7.2 and 10 years for TV, refrigerator, washing machine and air conditioner, respectively, which are relatively smaller than the estimation in Japan. It is found, however, that since the second hand market is active in Vietnam, total lifetime is estimated to be about 1.8-2.5 as long as those in Japan when considering repeated use of the devices.

Introduction

In the last few years in Vietnam, a trend for prices to go down was drastic and therefore many electronic devices become more affordable for even the low-income people in rural areas. This trend brings about a shortage in their lifetime, leading to an increase in the number of end-of-life products. Since any special treatments such as appropriate recycling are hardly made in Vietnam at this moment, problems such as public health and resource security are about to become probable in near future. Thus, it is of great importance to figure out the lifetime of various appliances, but less attention has been paid so far. Thus, the purpose of this study is to estimate the lifetimes of various electronic devices in Vietnam.

Method

Television, phone, personal computer, refrigerator, washing machine, and air conditioner, etc. were selected as target products. For the estimation of lifetime, questionnaire investigations were carried out mainly in Hanoi city in 2007 and 2012. As for the former, the survey was done at two Universities: Hanoi Industrial University and Hanoi National University. The questionnaires were distributed to 1,904 students. Students took questionnaires back to their family during the Tet holiday (traditional Vietnamese new-year holiday) and completed it before returning. Some inappropriate answers were excluded from analyses. The other survey, using the same answer sheet was also conducted to 184 households in Hanoi area. The households were selected first from high-educated relatives and friends with the complete explanation, and then those interviewees continued to ensure that their reliable relatives and friends fill in the questionnaires and so on.

Results and discussion

Figure 1 shows distribution of manufacturer for television, washing machine, refrigerator and air conditioner in Vietnam in 2007(Nguyen, Yamasue, Okumura, & Ishihara, 2009).

It is found that almost all of home appliances were made in Japan or Korea in 2007. Especially, the ratio of Korea was relatively high in case of TV, while Japan was high in cases of washing machine and refrigerator.

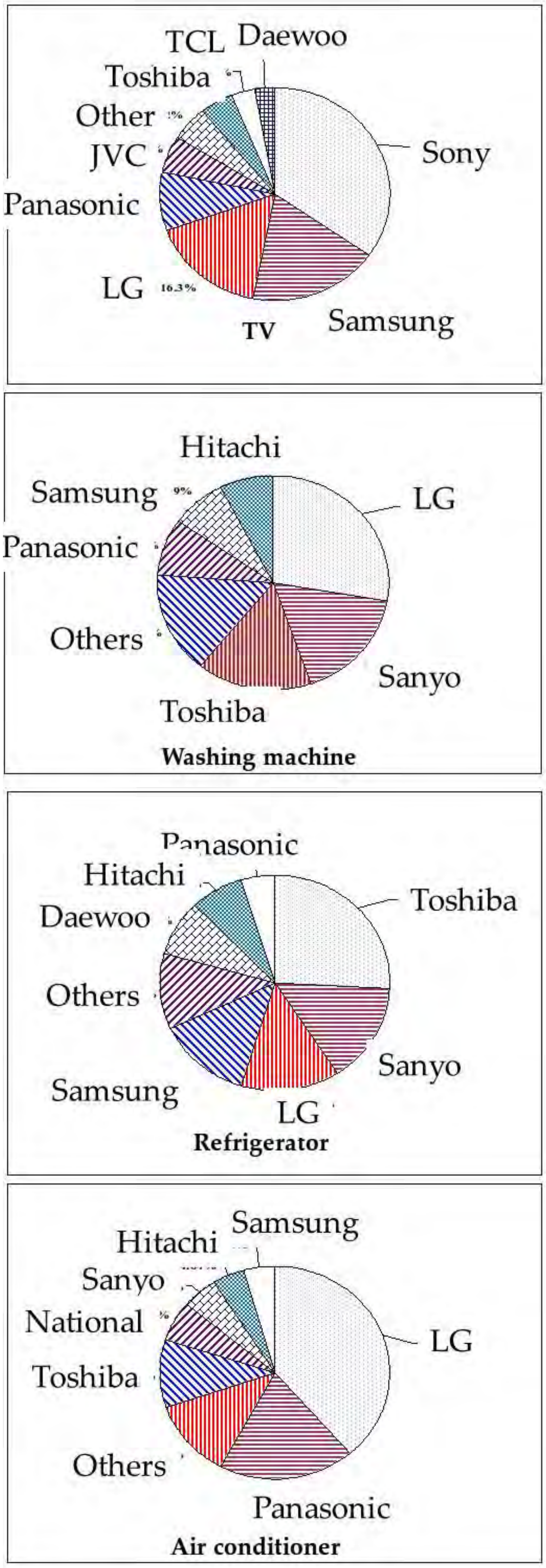

Figure 1. Distribution of manufacturer for television, washing machine, refrigerator and air conditioner in Vietnam in 2007.

Figure 2 shows the estimated possession ratio for color TV, refrigerator, washing machine, computer and air conditioner in Vietnam in 2007. It was found that the possession ratio is increases with an increase in household income. But it is still less than 80 % for air conditioner even for the highest income group.

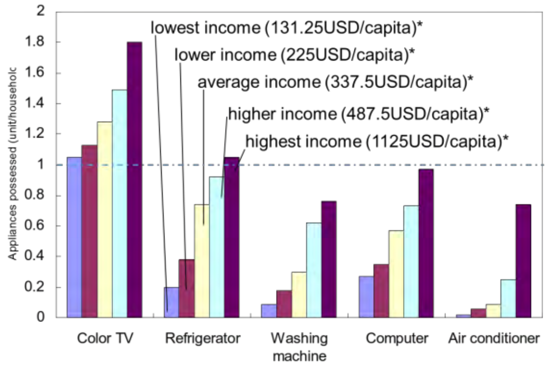

Figure 2. Possession ratio for color TV, refrigerator, washing machine, computer and air conditioner in Vietnam in 2007.

The estimated lifetime based on Weibull distribution for the four home appliances is shown in Figure 3.

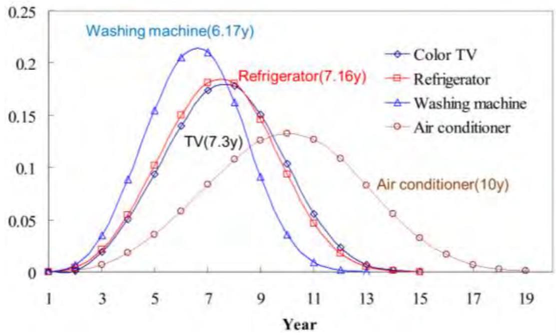

Figure 3. The estimated lifetime of four appliances.

The lifetimes are shorter than those seen in Japan. It is also found that there are differences not only in lifetime but also in possession ratio between the urban area of Hanoi and Ho Chi Minh cities.

It is found that Vietnamese people tend to sell end-of-life products or to keep them in their house rather than to bring them to a collecting agent. This would be due to: (1) their nationality, (2) benefit from end-of-life products, (3) lowness of normative consciousness, (4) lack of the proper legislation system that can force the stakeholders to obey the law, and (5) the living standard is still not high enough to eliminate uncontrolled markets. This has been the situation since at least 2006.

In order to consider repeated use, a Markov chain model using transition probability matrix has been applied (Nguyen, Yamasue, Okumura, & Ishihara, 2008). As the results show, it was found that TV, refrigerator, washing machine and air conditioner are used for 19.7, 18, 18.3 and 27.1 years for their entire life cycle, respectively. This indicates that although their used lifetime from brand new is shorter than those in Japan, active second-hand market contributes to increase in their entire life time 1.8-2.5 as long as those in Japan.

Conclusions

The lifetimes and possession ratios of various electronic devices (colour television, refrigerator, washing machine, air conditioner and personal computer) were investigated. The number of possession per household is increased with increase in household income for all devices investigated. The average lifetimes assuming Weibull distribution were estimated 7.3, 6.2 7.2 and 10 years for TV, refrigerator, washing machine and air conditioner, respectively, which are relatively smaller than the estimation in Japan. It was found, however, that since the second hand market is active in Vietnam, total lifetime is estimated to be about 1.8-2.5 as long as those in Japan, when considering repeated use of the devices.

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Exploring the relationship between the presumed quality and durability of fast-fashion garments, by the Generation-Y, female consumer

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Keywords: quality; fast-fashion; Generation-Y; sustainability; durability.

Abstract: The fast-fashion phenomenon uses a production model that relies on a quick replenishment cycle of low quality garments at cheap price points (Levy & Weitz, 2008; Caro & Martinez-de-Albeniz, 2012). Therefore every month and in some cases every week, new stock is delivered into the store (Palomo-Lovinski & Hahn, 2014) meaning the opportunity for customers to purchase new garments is increased. In addition, the business system of fast-fashion actively encourages the over consumption of garments (Rissanen, 2013). This over consumption has an environmental impact, mainly due to the way in which garments are produced as it consumes a huge amount of the earth's natural resources (WRAP, 2012) and they are not being renewed (Grose & Fletcher, 2012), nor are they being returned back into the system (McDonough & Braungart, 2002). Furthermore, many fast-fashion retailers are selling garments that are used fewer than ten times (McAfee, Dessian, & Sjoeman, 2004) in some cases even shorter lifetimes were recorded, with many items being worn only a few times before being discarded (Birtwistle & Moore, 2006). Conversely, fast-fashion garments are not made any differently than any other garment. Therefore, a study was conducted which observed and interviewed fourteen Generation-Y fast fashion customers whilst they assessed the quality and predicted the life spans of twenty-one fast fashion summer dresses. The results of the study will help examine how this group relates the quality of a garment to its length of life.

Introduction

This paper will consider the relationship of quality and durability of fast-fashion garments from the perspective of the Generation-Y, fast-fashion female consumer. Therefore this will begin with an overview of the fast-fashion industry, which will lead into outlining its environmental impact. The consumer will then be considered in relation to what motivates them to select and consume fashion garments. Finally, quality and durability will be looked at with regards to the customer and the industry. It is within these sections where the specific research questions (RQ) will be generated. These will be considered by looking at some of the results of 'Fast-fashion consumer quality assessment study'.

Fast-fashion

Overview

The term fast-fashion represents the part of the fashion industry that has four distinct elements; (i) on trend fashionable clothes, predominately for consumers under 40; (ii) affordable prices in the mid-to-low range; (iii) quick response time; and (iv) frequent assortment changes (Caro & Martinez-de-Albeniz, 2014). In addition, Fernie, et al (2004) outlined it as the business strategy that allows retailers to reflect current and emerging trends quickly. Furthermore, Hennes & Mauritz (H&M) suggests its global success is down to three factors: inventive design, the best quality at the best price, and efficient logistics (Tungate, 2008).

Fast-fashion consumer

The efficiency of the logistics ensures that these inventive, best quality, at the best price garments are constantly available for the customer to purchase. Furthermore, as fast-fashion garments themselves are not high in cost, nor do they require a high level of psychological investment (Gabrielli, Baghi & Codeluppi, 2013) it is easy for the customer to have their demand met (Barnes & Lea-Greenwood, 2006).

These demands stem from the fashion customer consumption drivers, which are; hedonism, symbolism, self-esteem and how others perceive them (Brewer & Gardner, 1996) and the garment choices are limitless, accessible and always new (Ibid). This requirement for the 'new' is responded to through quick consumer-driven trends (Varley, 2001, Barnes & Lea-Greenwood, 2006) which can be replaced by the next trend almost immediately (Christopher, Lowson & Peck, 2004; Tungate, 2008). Resulting in the fast-fashion consumer being presented with an unprecedented level of choice and availability of garments (Birtwistle, Siddiqui, & Fiorito, 2003). However, this availability and choice means a short existence for the garment, as outlined by Kadolph (2007, p. 33) "many products have a short life span. Even basic goods may change as fashion changes or with the seasons of the year. Rapid product change is a given for many textile products. Rapid product changes make it difficult to conduct a satisfaction assessment." Therefore this short lifecycle makes it difficult to confirm if the fast-fashion customer is satisfied with the purchases they make or even if they find the short lifecycle of benefit.

Fast-fashion and the environment

The fast-fashion system has two main ways it impacts the environment, the first being the production; through the manufacturing and finishing of the garments, and the second; being the ongoing need and drive for change which is at the heart of the consumption needed by the industry; which in turn fuels the production phase (Gertsakis & Neil 2011; WRAP, 2012). Due to the speed of replacement, there is limited opportunity to recoup the initial environmental impact of the garment, through an extended use phase (Klepp, 2005; Fletcher, 2008; Cooper, 2010; Gwilt & Rissanen, 2011). Subsequently, with the low cost of the garments and the industry having this fast re-purchase frequency, the garments are often seen as throwaway (Birtwistle & Moore, 2007).

> *"These mass-market practices have now become an albatross of expensive waste and excess, resulting in the fashion industry becoming entrenched in a series of bad environmental habits for an un-maintainable economic profit"* (Palomo-Lovinski & Hahn, 2014, p. 89).

This consumption of Earth's natural resources originating from fast-fashion represents one fifth of the entire fashion market share, and this amount is increasing (DEFRA, 2011). Subsequently, the resources, which are being used up within this activity, are not being renewed (Fletcher & Grose, 2012), nor are these resources being looped back into the system (McDonough & Braungart, 2002). Meaning that the cost of this consumption practice is ultimately being born by the environment at large. "In fashion…the cost implications of the growth model are mainly felt outside the corporation: by society at large, by workers and by the environment. Costs are experienced as increased pollution, resource depletion and climate change" (Fletcher & Grose, 2012, p. 126). However to reduce consumption and increase the length of time the garment is used for, rather than simply requesting the customer to buy less or do without (Palomo-Lovinski & Hahn, 2014), and having a better comprehension of the motivations that encourage and justify this over-consumption; would help enable a long-term and sustained change to be found (Soper, 2015).

Generation-Y consumers

The purchase motivators for this group as outlined by Noble, et al (2009, p. 626) are as follows:

- Assertions of freedom from parents
- Finding yourself
- To blend in
- To stand out
- Brand personality
- My personality
- Fashion knowledge
- Value-seeking
- Comfort of brands.

These themes are often used in conjunction with each other, for example Gen-Y are likely to be selecting their own clothing, are style conscious and shop within the value section of the market (Yip, Chan & Poon, 2012). The theme that would help the consumer decide the garment they want and when it should be discarded would be the consumers' *fashion knowledge* (Noble, et al, 2009). Furthermore, how fashion knowledge relates to an understanding of a garment can be framed by the theory of intrinsic and extrinsic criteria; intrinsic being all of the aspects of the product itself and extrinsic, is all of the aspects that sit outside of the physical product (Jacoby & Olson, 1972). A study by Eckman, et al, (1990) outlined that when making a comparison of the extrinsic and intrinsic criteria; overall the intrinsic criteria's' were more often used and related to the evaluation of the garment; colour, pattern, style and fit. Subsequently, it was these attributes that had the largest affect on consumer purchase decisions (Ibid). In addition, Jacoby & Olsen (Ibid) showed that intrinsic attributes were more important than extrinsic attributes in shaping the customers judgment of quality. However, the main drivers for quality considerations by the fashion industry have not been the intrinsic, but the extrinsic (Fiore & Damhorst, 199, p.168).

Quality assessment

Considering the work of Kincade, (2007, p. 30) who states:

> *"customers in general are uninformed about the quality or the standard of a garment, and in most cases there is a challenge for the 'measureable' industry standards meeting the customer's interpretation who are somewhat 'emotive' and vague when they discuss quality".*

These contradictory comprehensions of quality, has resulted in a disconnection between the consumer and the industry. This is compounded by each individual consumer having their own way of approaching quality assessment, that is relative to their needs, aspirations and personal history (Hugo & Van Aardt, 2012).

Therefore, any new developments of quality assessment within mass-market fashion, has been from an industry and systems based perspective (Lo & Yeung, 2004), and have been developed to ensure constant improvement and alignment with competitive priorities, and not from the customer's perspective (Birtwistle, Siddiqui & Fiorito, 2003; Christopher, Lowson & Peck, 2004; Kim, 2013) and the desired outcome is increased sales (Saricam, et al 2012). In addition, when the question of quality is approached from the position of the consumer, it focuses invariably on the higher end of the market and considers only high quality (Koskennurmi & Päivikki, 2005), and there is little evidence of the industry wanting to improve the level of quality, at the cheaper end of the fashion market.

Quality reduction

Paradoxically, the level of industry quality standards, for modern cheap fashion have experienced (Cline, 2012, p. 90) a systematic 'quality fade'. Resulting in the production and acceptance of lower quality items to be the norm. Resulting in the majority of consumers losing the ability to determine good quality over bad (Ibid). Furthermore, this lack of consumer quality assessment understanding, is specifically an issue for the Gen-Y consumer,

> *"Quality had been whittled away little by little, to the point where the average store-bought style is an extraordinary thin and simple, albeit bedazzled and brightly colored, facsimile of a garment. Yet I suspect few consumers born after 1980 have any idea of what they're missing"* (Ibid, p. 90).

Therefore, the Gen-Y customer is both unaware and unable to determine the level of quality they are entitled to, thus creating a situation where the quality can be continually reduced, to aid the speed of the fashion cycle (Ibid). This reduction of quality has been gradual, "In order to shave costs, fabrics have became thinner and lighter over the years" (Ibid, p. 89)

This intentional cost saving, through reduction in the weight of the textiles, serves as an indicator of a wholesale quality reduction since the early 1990's. However it is not limited to the textiles, (Ibid, p. 89-90) "Cheap clothing skimps on such labor-intensive details as lining, gussets, stronger seams" this, as Cline suggests, is a noticeable decline of every aspect of the garments durability and quality, resulting in garments being made "for so cheap that you can not even wear it once and it falls apart" (Ibid).

RQ1: Can it be shown that the fast-fashion respondents each have their own interpretation of quality?

Durability

Therefore, the approach taken by the customer within the determination of quality and its impact on durability of the garment is neither reflective nor derived from the requirements of the industry, but of the individual (Stamper, et al., 1996, pp. 11-12).

> *"the concept of quality or value as a direct correlate of durability must appear*

foremost in the minds of many consumers during a casual discussion of the term, in fact aesthetic concerns actually dominate most traditional treatments of apparel quality…research studies of measured quality or consumers' concepts of quality often focus on construction details, which are more closely related to the appearance of the garment in question and than its expected durable life. A hem that is uneven in length is just as durable in most cases as one that is perfecty aligned, but the perception is that the uneven garment is of poorer quality."

As can be seen, this focus on the construction details, whilst uninformed about the nature of these details, displays an overriding willingness for the aesthetic to be perfect; and is prevalent over the item having the ability to last for a long time (Tungate, 2008). Resulting in the mass-market customer seeing the aesthetic level of the garment as the most important factor (Swinker & Hines, 2006:221). This results in system where the new look is the primary driver. Using Cooper (2010, p. 8) and adapting his work on product life-times to reflect fast-fashion consumption, it could be seen that the industry is based predominately on the 'replacement life' model, occasionally the 'service life' and rarely the 'technical life'.

RQ2: Does this consumer group relate the quality of a fast-fashion garment to its durability?

The study

The study consisted of observing and interviewing, fourteen Gen-Y female, fast-fashion consumers. Each respondent was observed inspecting a rail of twenty-one summer dresses and were asked questions about the durability; price; brand; quality; colour; textile and disposability of the dresses.

These categories represent a range of aspects which investigate how the fast-fashion consumers, relate quality to durability. However or this paper, specific response to the two RQ's will be shown, as these are most related to the analysis of product lifetimes.

To provide a control measure and to ascertain any differences between the fast-fashion consumer a fast-fashion garment and textile-testing specialist, also took part in the study. All of the fifteen participants assessed the same rail of dresses purchased from fast-fashion stores in London during July 2014.

The results

RQ1: Can it be shown that the fast-fashion respondents each have their own interpretation of quality?

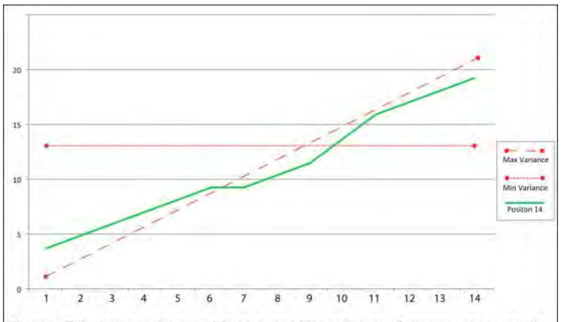

Chart 1. This shows is the possible Max and Min varience of arrangements on the ordinal scale for the quality (q) question. Therefore it can be seen that the respondents are almost at the maximum amount of varience for each of their individual arrangments.

For the quality assessment question (q), each of the respondents were asked to rank the dresses in order of quality, (position 1 being the lowest and 21 being the highest) each of the respondents' moved the 21 dresses into a ranking that produced a individual ordinal scale for each. However, (see Chart 1. above) the final arrangements of the dresses was so highly varied, there was almost no duplication, agreement or consistencies shown within the respondents arrangements.[1] The one notable agreement came when 43% of the respondents selected dress number 13 (see Figure 1) as representative of it being the highest quality.

Therefore in response to RQ1, the findings did show that each of the fast-fashion respondents did have a highly individualized interpretation of quality.

[1] The 30 deg dashed line, represents Maximum variance in the answers, the horizontal dotted line shows Minimum variance, and the green line shows the final (q) accumulated responses.

013 Fig 1. White Cotton shirt dress from ZARA

RQ2: Does the fast-fashion consumer see a relation to quality and durability?

As can be seen previously, when asked to 'rank the dresses in order of quality (q)' each of the respondents' used an ordinal scale to provide a unique ranking. This was replicated, for the 'rank the dresses in order of durability (d)'. The results were tabulated and the two distinct categories (q) and (d) were overlaid for comparison.

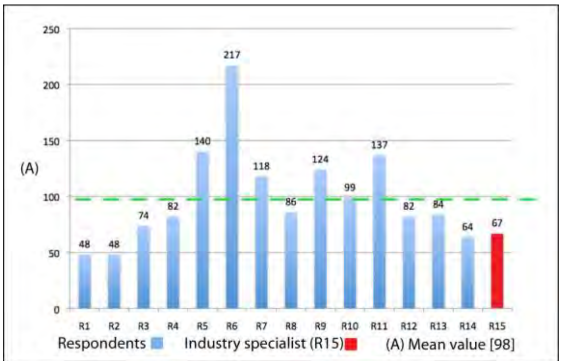

Table 2. The amount of adjustments (A) made to the ordinal scale arrangement of quality (q) compared to durabilty (d) by each of the respondents (R).

Table 2 shows the amount of adjustment (a) that took place between the ordinal scales for (q) and (d). For instance, if a dress was in position 4 on the on the (q) scale, and then placed in position 10 for the (d) scale then the amount of adjustment (A) would be 6.
Therefore, the closer (A) gets to 0 (meaning no change of relative position) then the closer the respondent saw (q) and (d).

This was completed for each of the respondents and the overall mean value of (A) can be seen in the dotted horizontal line at 98 (A). Therefore, as the range is between 0 and 250 for (A) the mean being placed at 98, and with nine of the respondents positioned below 100, would indicate that the (q) and (d) are seen as having a correlation by this consumer group. Furthermore, as can be seen with R15 (red column) the industry specialist believed more strongly of a relation between (q) and (d) as it fell well below the mean value of the group, and was 4th lowest. The actual dresses selected can be seen within the triangulation chart (see chart 2 below). This shows the eleven of the twenty-one dresses, the industry specialist believed had very similar (d) and (q) values.

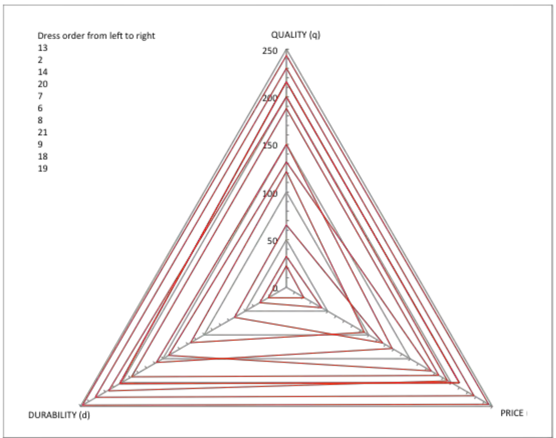

Chart 2. Displays the triangualtion of the results that showed is consistency with (d) and (q) as decided by the industry expert.

Discussion

The two research questions returned a decent level of insight, which would justify some future effort into further investigation of the relationship between (d) and (q). However it is important to continue to ask these questions from the perspective of the consumer. There is clear evidence that the fast-fashion consumer in general, is unable to understand or even discuss quality from a unified perspective. Therefore one must question the motivation of the industry to enter into a debate around appropriate levels of quality, when the customer cannot currently comprehend or even measure it (Zeithaml, 1988). Subsequently, a possible avenue may be to continue and consider quality, durability but also price. As this would take into account the interests and motivations of all of the stakeholders. There are a few direct recommendations for potential future study from the work presented here, these are:

1. For further investigation into the Gen-Y, fast-fashion consumers capacity to have a common and applicable interpretation of garment quality.

2. How the fast-fashion consumer perceives the relationship, if any, between quality, durability and price?

3. And finally, how might the industry respond to these three factors, if the customer views them as being intrinsically related?

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